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ABSTRACT

As part of the 1977 British Columbia Mathematics Assessment, over 100,000 students from Grades 4, 8, and 12 were given tests designed to measure mastery of a limited number of important mathematical skills and concepts. Approximately 3,500 teachers of mathematics at seven different grade levels completed comprehensive questionnaires dealing with aspects of mathematics instruction in the province. This report is one of a four-part series and discusses the Student Test phase of the project. It contains a detailed exposition of the results, interpretation, and recommendations based on the student tests as well as the process of identifying the specific concepts and skills that were assessed. In addition to this report, a Summary Report gives the highlights of the entire project, Report Number 2 gives a detailed discussion of the Teacher Questionnaire phase, and Report Number 3 gives a review of the items and data from both the Student Tests and Teacher Questionnaire. (MN)

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BRITISH COLUMBIA
MATHEMATICS ASSESSMENT
1977

U.S. DEPARTMENT OF HEALTH,
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Test Results

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A REPORT TO
THE MINISTRY OF EDUCATION
PROVINCE OF BRITISH COLUMBIA

SE 023 990

The B.C. Mathematics Assessment

Report Number 1

TEST RESULTS

This report was prepared for the Learning Assessment Branch of the Ministry of Education by

David F. Robitaille
James M. Sherrill

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September 1977

The British Columbia Mathematics Assessment

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TABLE OF CONTENTS

		Page
1.	Introduction	1
2.	The Goals Assessment	15
3.	Grade/Year 4 Results	31
4.	Grade 8 Results	73
5.	Grade 12 Results	117
6.	Grades 4, 8, 12: Common Items	163
	Appendices	
A.	Pilot Test Schools	181
B.	Review Panels	183
C.	Curriculum Revision Committee	187
D.	Interpretation Panels	193

CHAPTER 1

INTRODUCTION

In the spring of 1977, students enrolled in Grades 4, 8, and 12 in the public schools of the province of British Columbia took part in the first Assessment of Student Learnings in Mathematics conducted by the Learning Assessment Branch of the Ministry of Education. During the same period, approximately 3500 teachers of mathematics at seven different grade levels completed a comprehensive questionnaire dealing with numerous aspects of the methods and materials used in the teaching of mathematics in the province.

The Learning Assessment Program is longitudinal in nature, and the various aspects of the curriculum of the public schools are scheduled to be assessed at regular intervals. In the case of mathematics, the cycle is two years long; in other words, mathematics will be re-assessed during the 1978-79 school year. One of the purposes of this assessment of mathematics in the province was to collect baseline data against which the performance of students in future assessments could be compared.

1.1 Purposes of the Assessment

The major principle underlying the entire Learning Assessment Program is that decisions about education should be based upon an understanding of what and how children and young adults are learning. Educational decisions are being made every day, decisions which affect the allocation of resources, in-service education of teachers, teacher training programs, curriculum development, and the adequacy of various programs. The Mathematics Assessment will provide decision-makers at all levels with factual and current information concerning the teaching and learning of mathematics upon which to base their decisions.

The Assessment Program in general and the Mathematics Assessment in particular are designed to inform the public of some of the strengths and weaknesses of the public school system in this province. The information generated by the Mathematics Assessment will assist school districts in maintaining identified strengths and overcoming weaknesses. It is hoped that curriculum developers and curriculum revision committees will be able to make use of these results in the process of improving curricula and developing suitable resource materials. Furthermore, such information could be used in the allocation of resources at both the provincial and district levels.

At the university level, the information generated by the assessment will be useful in indicating directions for change and improvement in teacher education. Finally, the information produced by the assessment should be of great value to educational researchers both as a data bank and as a source of researchable questions concerning the teaching and learning of mathematics.

1.2 Organization of the Assessment

Several groups participated in the organization and implementation of the Mathematics Assessment. These groups included the Learning Assessment Branch of the Ministry of Education, the Contract Team, the Management Committee, and the B.C. Research Council. Consultations were held with several other groups as well.

The Contract Team was retained by the Learning Assessment Branch to conduct the Mathematics Assessment. The Contract Team's responsibilities included conducting the Goals Assessment and developing the set of objectives to be assessed, constructing the student tests, piloting the tests and subsequently revising them, constructing the Teacher Questionnaire, and writing the final reports of the assessment. The Contract Team consisted of two members of the Faculty of Education of the University of British Columbia, a primary teacher who was on leave of absence from the New Westminster School District, and a teacher of secondary mathematics from the North Vancouver School District.

It was the role of the Management Committee to oversee the operations of the Contract Team and to provide guidance and suggestions regarding the various phases of the assessment. Members of the Management Committee included two teachers, a supervisor of instruction, a teacher educator, a school trustee, the chairman of the Contract Team, and representatives of the Learning Assessment Branch.

The B.C. Research Council, under the direction of the Contract Team, conducted the majority of the technical and administrative aspects of the assessment. Their responsibilities included overseeing the printing and distribution of the tests, answer cards, and teacher questionnaires, conducting the scoring and data analysis, and serving as statistical consultants and advisors to the Contract Team and the Management Committee.

Consultative meetings were held with several groups. Representatives of the Contract Team met with the Mathematics Curriculum Revision Committee to discuss aspects of the assessment. In addition, Review Panels were organized by the Learning Assessment Branch to discuss the objectives to be tested in the Mathematics Assessment. Such panels were intended to be as widely representative as possible of the various groups interested in the mathematics achievement of students. (Additional information concerning the structure and operation of such panels is given in Chapter 2.) Finally, meetings were held and correspondence exchanged with representatives of other assessment programs in North America, in order that the B.C. Mathematics Assessment could benefit from their experiences.

1.3 Components of the Mathematics Assessment

The Mathematics Assessment consists of four major components: the Goals Assessment, the Student Tests, the Interpretive Analysis, and the Teacher Questionnaire. The last component is the subject of a separate volume (Report Number 2) and will not be discussed in any detail here. The first and second components constitute the substance of this report and will be more thoroughly discussed in subsequent chapters. The rationale for and the procedures followed in conducting the Interpretive Analysis are treated in this section.

1.3.1 The Goals Assessment

It was not within the terms of reference of the Mathematics Assessment to attempt to evaluate students' achievement in mathematics in any particular course or program, or to evaluate the entire mathematics curriculum. Neither was it the objective of this assessment to obtain information on the achievement of individual students or schools, nor on the performance of teachers of mathematics. It was the objective of the assessment to obtain, and to make widely known, information regarding the present state of student learning in mathematics on a province-wide basis. In addition, each school district is to be provided with a summary of its own results.

The initial and basic decision regarding the Goals Assessment was to limit the mathematics content to be assessed to topics which most informed observers would agree are among the essential concepts and skills of mathematics at the three levels tested: end of primary education (Grade/Year 4), end of elementary education (Grade 8), and end of public schooling (Grade 12). Three levels of cognitive behaviour, called domains in the assessment, each subdivided into a number of objectives made up the basic framework of the Goals Assessment.

The process of identifying the specific concepts and skills to be assessed was based primarily upon the recently revised curriculum guide for mathematics in British Columbia. In addition to this basic document, several other sources were consulted and utilized. Chapter 2 contains a detailed exposition of this procedure, as well as of the rather extensive consultation that took place throughout the Goals Assessment phase of the project.

1.3.2 Student Tests

Tests were constructed to measure students' mastery of the objectives identified in the Goals Assessment phase. A separate test was prepared for each of the three grade levels involved. For each test, a total administration time of ninety minutes was allotted: thirty minutes for instructions, distribution, and collection of the test booklets and answer cards, and sixty minutes for completion of the test. A discussion of the reliability of the students' tests is contained in the Technical Report.

Pilot testing of the assessment instruments was conducted during the late fall of 1976 in several school districts across the province. (See Appendix A for a list of the schools which participated in the pilot testing.) Approximately 250 students at each of the three grade levels involved wrote the tests, and their results were used in deciding upon the final form of the tests.

On the basis of the pilot testing certain items were deleted, others were added, and still others were modified. The majority of modifications to items represented efforts to improve the readability of the stem of an item or the plausibility of the distractors. All additions and modifications were then tried out before being included in the final versions of the tests.

A second purpose of the pilot tests was to ensure that students had sufficient time in which to complete the tests since they were not intended to be speed tests. Results showed that the majority of students at each grade level required significantly less than the total time allotted, and that virtually everyone was able to complete the test in less than one hour.

With the exception of a portion of the Grade/Year 4 test, all of the test items were cast in multiple-choice format with five foils or distractors for each item. In every case, the foils consisted of four possible answers to the item while the fifth foil was "I don't know". The "I don't know" option was used in an attempt to minimize guessing and in order to provide an outlet for students who, for one reason or another, had not been exposed to the material being tested or had forgotten it. (For a more complete discussion of the use of "I don't know" as a distractor in the Mathematics Assessment tests, see Robitaille, 1977.)

In an effort to assess change in students' abilities to deal with certain concepts and skills, some items appeared on two or more of the tests. For example, the same five items dealing with knowledge and understanding of the units of the metric system of measurement were used on all three tests. In several of the skill areas, the same item or items appeared on the Grade/Year 4 and 8 tests, or on the Grade/Year 8 and 12 tests. Overall, there were nine items common to the Grade/Year 4 and 8 tests and forty-three items common to the Grade/Year 8 and 12 tests. This includes five items which were common to all three tests.

The International System of Units (SI) was utilized for all test items involving measurement; no items contained British or Imperial units of measurement. Furthermore, any numeral containing five or more digits was written with a space between periods rather than a comma (43 256 not 43,256) and any decimal fraction with absolute value less than one was written with a zero before the decimal point (0.86 not .86), except in the case of computation items.

The decision to use the metric system of measurement exclusively did restrict, to some degree, the number and the nature of problem-solving items involving measurement concepts. For example, it was felt that including items dealing with the purchase of consumer goods such as carpeting, or concrete, or the like, in terms of metric units of area or volume would make such items appear overly unrealistic and unfamiliar since these terms and units are not yet in widespread use by consumers in our society. On the other hand, since the curriculum guide does call for implementation of the metric system of measurement in the schools, any reference to the British system was avoided.

1.3.3 Interpretive Analysis

As part of the Language B.C. project which took place during 1976-77, the Learning Assessment Branch assembled a panel of eleven educators and assigned them the task of interpreting the assessment results. Such an approach to the interpretation of assessment results is not without its problems: the procedure is necessarily subjective in nature, the panel members may not be truly representative of the various groups having an interest in the results, and furthermore, such an analysis might give a false impression of precision or exactitude by assigning numerical values to decisions based on such subjective information.

On the other hand, no assessment program would be complete without some type of interpretation of the raw data. Since no objective standards existed at the time of the assessment, some form of Interpretation Panel analysis was the only choice available. A discussion of some of the difficulties inherent in interpreting assessment results may be found in Weiss and Conaway (1976).

Three fifteen-member Interpretation Panels, one for each of the three grade levels involved, were constituted by the Learning Assessment Branch. Each panel consisted of seven teachers of mathematics at the particular grade level, two supervisors of instruction, two teacher educators, two school trustees, and two members of the public at large. Every panel member received a copy of one of the three assessment instruments along with information and instructions.

Prior to meeting as a group, the members of each Interpretive Panel were asked to perform several tasks, keeping in mind the age and level of the total population of students to which the test was administered:

(1) answer each question on the test and check their responses using the answer key provided,

(2) review the booklet in which the test items were organized into objectives and domains,

(3) establish, in percentage terms, two levels of performance for each item -- "acceptable" and "desired", remembering the range of individual differences among students as well as the variation in programs throughout the province, and

(4) record the two levels for each item on the form provided for that purpose.

At this stage, the panel members were not given access to the actual results obtained by the students.

The panels met in Vancouver in early June. Each panel was chaired jointly by a member of the Contract Team and a member of the Management Committee. The panelists were first given the provincial results for their respective tests and asked to compare the actual result obtained for each item with the range (acceptable to desired) which they had established earlier for that item. Using that range as a general focus for consideration rather than as a specific, arbitrary range allowing no latitude, they were then asked to rate each item on a five-point scale of satisfaction:

5 = Strength
4 = Very satisfactory
3 = Satisfactory
2 = Marginally satisfactory
1 = Weakness -- poor performance

The criteria of satisfaction were unique to each panelist and depended upon what each one 'felt' student performance on a given type of item should be. In arriving at their decisions, they were asked to bear in mind the following factors:

(1) the total population of students at this level in British Columbia,

(2) the wide range of individual differences present within the grade level,

(3) the considerable variation in instructional goals and/or methods throughout the schools of the province, and

(4) the difficulty of the items.

Upon completion of this individual task, the panelists formed seven sub-groups of two or three members in order to compare their ratings and to arrive at a consensus rating. They were also asked to record any comments they might care to make. The resulting seven sets of pair ratings were then averaged and discussed with a view to obtaining group agreement on each item. An opportunity was provided for strong minority opinions to be recorded.

Finally, each panel was divided into three group of five as follows:

Group A	Group B	Group C
1 Teacher Educator	1 Teacher Educator	1 Public
1 Supervisor	1 Supervisor	1 Trustee
2 Teachers	2 Teachers	3 Teachers
1 Public	1 Trustee	

Each group was assigned one domain (i.e., a set of related objectives) and was asked to provide anecdotal comments for each objective in its assigned domain. The comments were to identify strengths and weaknesses of student performance based upon the items used to measure the objective. In some cases, comments upon performance by students on individual items were given.

When all three groups were finished, the panel re-assembled to discuss the anecdotal comments. Modifications were made where they were deemed appropriate, and any strong minority views were recorded.

The information gained from the deliberations of the Interpretive Panels was used by the authors of this report in commenting upon the results of the assessment. Although the procedure used does lack some air of precision attributed to strictly numerical comparisons, the wealth of experience which the members of the panels brought to bear upon their examination and interpretation of the results gives their interpretations considerable credibility.

1.3.4 Teacher Questionnaire

Two questionnaires, one for teachers of elementary school mathematics and the other for teachers of secondary school mathematics, were developed for use in the Mathematics Assessment. The questionnaires, which were answered anonymously, dealt with various aspects of the teachers' backgrounds and training as well as with facets of the methodology of teaching mathematics at different levels, and with instructional materials used by teachers of mathematics.

Teachers of mathematics at each of Grades 1, 3, 5, 7, 8, 10, and 12 were systematically selected as potential respondents to one of the questionnaires. Those selected were mailed a questionnaire shortly after the administration of the student tests. Of the 3451 questionnaires sent out, 2955 were returned completed for a return rate of 85.6%. The data obtained from the questionnaires are analyzed and discussed in Report Number 2.

1.4 Student Characteristics as Reporting Categories

A number of factors are either known to be or are strongly suspected of being related to students' performance in mathematics. While it would not be possible to identify a casual relationship between a given student characteristic and performance on the assessment test as a part of the Mathematics Assessment, it is possible to identify variables that appear to be related on the basis of the data collected. Relationships so identified may lead to follow-up studies specifically designed to identify cause and effect relationships on the basis of the correlational results discovered in the assessment program.

As a part of each of the three Mathematics Assessment tests, students were asked to report on several aspects of their personal backgrounds. A list of the reporting categories which were used as well as the grade levels at which they were used is given below. Each is accompanied by a brief statement which attempts to explain why each such reporting category was used.

1.4.1 Mathematics Background (12)

Students with extensive backgrounds in mathematics will undoubtedly outperform students who, for example, have studied no mathematics since completing their last compulsory course in Grade 10. Many individuals and groups expressed an interest in seeing how this latter group of students would do on the test.

1.4.2 Date of Birth (4, 8, 12)

There is some evidence (Callahan and Glennon, 1975) that, in the lower grades at least, chronological age has an effect on mathematics achievement. Although the results are not consistent, older children appear to achieve better in mathematics than do their younger classmates and this effect seems to hold more for boys than it does for girls.

1.4.3 Sex (4, 8, 12)

There is currently a considerable amount of interest in the area of sex differences in achievement in mathematics. Several major studies, notably the National Longitudinal Study of Mathematical Ability and the National Assessment of Educational Progress (NAEP Newsletter, 1975) both in the U.S.A., have stated that boys, after the age of 13, consistently outperform girls at the higher levels of cognitive functioning in mathematics. More recently, Fennema (1977) has seriously questioned these conclusions and has obtained evidence which fails to show any sex differences in achievement.

1.4.4 Number of Schools Attended (4, 8, 12)

Many educators believe that there is an inverse relationship between the number of schools attended by a student and that students' achievement. Results from Language B.C. (Evanechko and Smith, 1976) showed a consistent decrease in performance in reading with an increase in the number of schools attended. As Evanechko and Smith warn, however, such results must be interpreted with caution. "It may not be the mere fact of moving to another school that results in lessened performance as much as it could be various emotional and social factors associated with the move or perhaps the instability of the family or even the family's socio-economic status." (p. 27)

1.4.5 Residence in Canada and Language Spoken (4, 8, 12)

Length of residence in Canada and language spoken were found to be quite highly related to reading performance in Language B.C. (Evanechko and Smith, 1976). As the percentage of non-native speakers of English in the schools of the province continues to grow, information concerning the relationship between that variable and achievement in all areas of the curriculum, including mathematics, will be increasingly important.

1.4.6 Number of Hours of Television Watched (4)

The cover story in a recent issue of Newsweek magazine discussed the predominatly negative effects on children of television watching. Among the many results in this area, the relationship reported by Language B.C. is interesting. "There is generally an increase in performance in reading with an increase in television watching up to two hours per day, then a slow decrease to the four or more hours per day category" (Evanechko and Smith, 1976, p. 32).

If any relationship between television viewing and mathematics achievement does exist, it may prove to be related in an important way to one or more variables more closely linked to school performance; e.g., time spent on out-of-class assignments.

1.4.7 Use of Hand-Held Calculators (4, 8, 12)

Hand-held calculators are fast becoming ubiquitous and will undoubtedly have an impact in the field of Mathematics Education. Although it may be too early to look for or to expect to find evidence of a relationship between use of such devices and mathematics achievement, educators should be aware of the extent to which students make use of calculators both in and out of school. In addition the data obtained now should be useful for comparison purposes in future assessments.

1.4.8 Time Spent on Homework (8, 12)

The evidence regarding the effect of homework assignments on students' achievement is, as is so often the case in education, equivocal (Callahan and Glennon, 1975). Perhaps because of this, teachers at all levels seem to be assigning less and less homework. With the information gained from this item, it is possible to compare performance on the assessment test with the amount of time students reported spending on homework.

1.4.9 Parents' Educational Background (12)

The National Assessment of Educational Progress reported that students' achievement in computation varied directly with the highest level of education attained by their parents (NAEP, 1975a). The data obtained here provide an opportunity to relicate the NAEP finding in a different social context.

1.4.10 Future Plans (12)

Students' future plans probably are highly correlated with their mathematics backgrounds. That is, the more academically oriented students will likely take more mathematics, perform better on the tests, and proportionally more of them will plan to continue their studies at the post-secondary level.

1.4.11 Out-of-School Work (12)

Many secondary students hold part-time jobs which occupy a considerable portion of their out-of-school time. The purpose of this item was to collect information which could indicate the direction, if any, in which such involvement affects mathematics achievement.

Assessment tests in Reading were also given at the Grade 8 and 12 levels, and these tests contained similar, and in some cases identical, background and information questions. For example, on both the Reading and the Mathematics tests, students were asked their date of birth, sex, and number of schools attended. Because of the common items, it was possible to merge the two sets of data and obtain a new data file containing the information and results obtained on both of the tests. Matches were obtained for 66% of the Grade 8 students and 63% of the Grade 12 students. This new file was used to obtain further information on student background, as well as to correlate some aspects of student performance in reading with the same students' achievement on some mathematics objectives. For example, it was then possible to obtain a measure of the correlation that exists between reading comprehension and the ability to solve mathematics problems.

The results obtained from the recording category data are discussed in Chapters 3 through 6. Not every comparison that was made has been reported. Because of limitations of time and space available, only those deemed to be most important or interesting have been mentioned.

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CHAPTER 2

THE GOALS ASSESSMENT

In the chapter, "A View of Education," Bloom *et al* (1971) list five areas they intend to encompass in their discussion of evaluation in education. All five areas are concerned with using evaluation to improve teaching and learning. Of the five areas, the one that generates the most immediate impact is, "Evaluation as an aid in clarifying the significant goals and objectives of education and as a process for determining the extent to which students are developing in these desired ways." (p.7-8). In general terms, the Mathematics Assessment measured the extent to which students were developing with respect to the essential skills of mathematics in British Columbia.

In more specific terms, the Mathematics Assessment measured the extent to which students at the end of their primary, elementary, or public schooling have mastered what might be termed the minimum essentials of mathematics. Many sources were used in deciding what to include as minimum essentials: i.e. what every student at the specified grade level should have learned. Some of the more useful of these sources are described below. References to specific publications which were of importance to the Mathematics Assessment are listed at the end of the chapter.

1. Publications of the National Assessment of Educational Progress: The Education Commission of the States created the Committee on Assessing the Progress in Education, which has since been renamed NAEP, to initiate a project through which ten areas of the curriculum, including mathematics, would be assessed on a nationwide basis on a three-year cycle. Mathematics was first assessed in 1972-73 and re-assessed in 1977. NAEP publishes individual papers, reports, and a newsletter.

2. Publications of the School Mathematics Study Group (SMSG): SMSG was undoubtedly the most influential of the groups that produced experimental mathematics curriculum materials during the 1960's and early 1970's. In addition, SMSG directed the National Longitudinal Study of Mathematicalbilities (NLSMA). NLSMA was a longitudinal study designed to assess the mathematical abilities of students in grades 4-12 during the period 1962-67. From 1958 through 1973 SMSG published many newsletters and reports.

3. Publications of the National Council of Teachers of Mathematics (NCTM): The NCTM published a series of articles dealing with NAEP results from the Mathematics Assessment in *The Arithmetic Teacher* and *The Mathematics Teacher* between 1975 to 1977. Other articles on assessing mathematical skills have appeared periodically in NCTM publications. The NCTM has also used its journals to publish articles on basic skills. A statement of NCTM's official position on basic skills appeared in the March 1977 issue of the NCTM *Bulletin for Leaders, March 1977.*

4. State Assessment Programs: Many states in the U.S.A. have implemented their own statewide mathematics assessments programs. The materials produced by several of the state assessment programs were useful in the planning of the Mathematics Assessment for British Columbia.

5. *Mathematics Curriculum Guide Years One to Twelve:* The official Mathematics Curriculum Guide issued by the Ministry of Education of B.C. was the one publication most frequently used in the planning of the B.C. Mathematics Assessment. The *Guide* contains the most accurate reflection of the current content presented in the mathematics classes in the schools of B.C., and includes the grade placement of the different mathematics topics.

The procedures used in going from a general set of statements about assessment to the specific objectives to be measured in the B.C. Assessment of Student Learnings in Mathematics are described in the remainder of this chapter.

2.1 Development of the Item Specification Model

On the basis of suggestions and ideas gleaned from the sources described above as well as from consultations with educators locally, work was begun on the development of an Item Specification Model (see Figure 2-1) for the Mathematics Assessment. As has been suggested elsewhere (Bloom, *et al*, 1971), the development of such a model is a necessary first step in the planning of any major evaluation program such as this assessment.

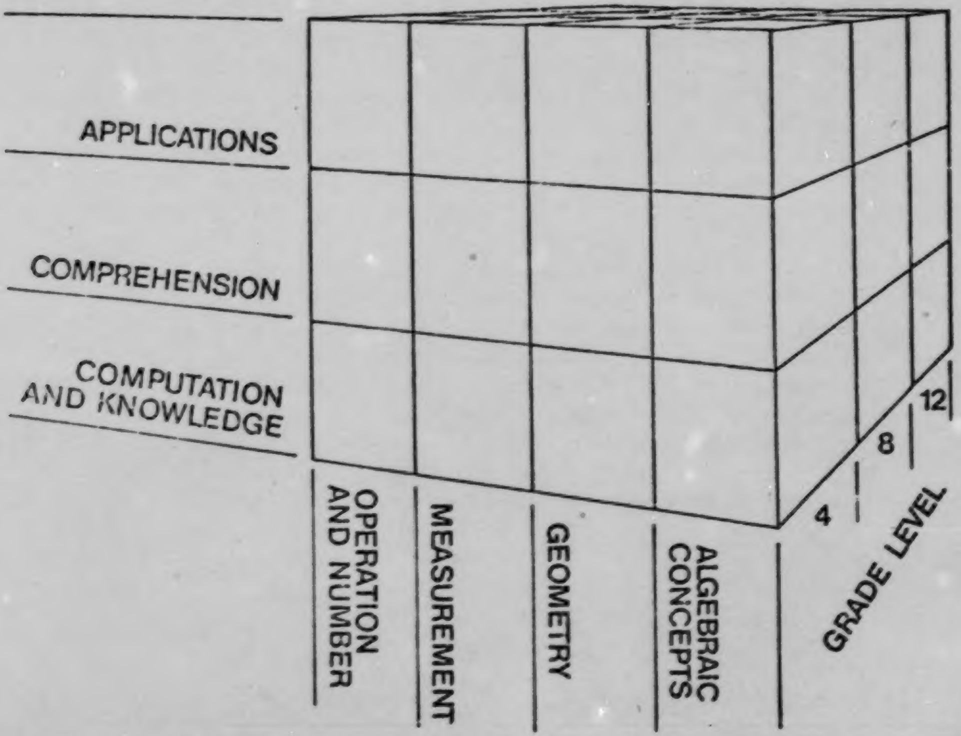

Figure 2 - 1: Item Specification Model for the B.C. Mathematics Assessment

All major assessment projects in mathematics, including NLSMA, NAEP, and the International Study of Educational Achievement (IEA) have developed models upon which to base their evaluations. The purposes served by the models may have varied, but their use is universal. One of the main purposes served by the Item Specification Model was that it focused attention upon the fact that mathematics achievement is multi-faceted. Since mathematics achievement is not a unitary trait, the assessment strategy applied must include different measures of various aspects of mathematics.

Mathematics achievement is multi-faceted; the Item Specification Model is multi-dimensional. The first dimension on the model is grade level. As described earlier, the three points on the K-12 continuum selected for testing were end of primary education, elementary education, and public schooling. Since one cannot reasonably expect that all of the Grade 3 mathematics curriculum has been covered before the end of year 3, the assessment instrument was administered in year 4. Similarly Grade 8 was chosen for administration of the end of elementary education assessment. In order to assess student performance in mathematics at the end of their public schooling, the assessment instrument was administered to all students in Grade 12. However, since mathematics is not required after Grade 10, the mathematics content on the assessment instrument administered in Grade 12 was restricted to the Grade 10 level or below.

The second dimension of the Item Specification Model is content, that mathematics which was to be tested. Of all the major mathematics content areas that could have been used, the following four were selected: Number and Operation, Measurement, Geometry, and Algebraic Concepts. Topics classified as belonging to the Number and Operation category dealt with the nature and properties of whole numbers, integers, rational numbers, and real numbers as well as with techniques and properties of arithmetic operations. The Measurement category included topics such as selecting the most appropriate unit of measurement, familiarity with metric units of measurement, area and perimeter, angular measurement, and scale drawing. Topics in the Geometry category dealt with the identification of geometric figures, classification of angles and triangles, parts of the circle, and the Theorem of Pythagoras. Topics in the Algebraic Concepts category were concerned with graphs, writing algebraic expressions, simplifying and evaluating polynomials, linear and quadratic equations, slope of a line, and simultaneous equations.

The final dimension of the Item Specification Model consists of three levels behavior, which are referred to as domains. Definitions and Applications, were adapted from Wilson's definitions of cognitive behaviours (Wilson, 1971, p. 648-649). The Computation and Knowledge domain encompasses areas such as knowledge of specific facts, knowledge of terminology, and ability to use algorithms. The Comprehension domain includes knowledge of concepts, knowledge of principles, rules, generalizations, ability to transform problem elements from one mode to another, and ability to read and interpret a problem. Ability to solve routine problems, ability to analyze data, and ability to recognize patterns belong to the Applications domain.

The domain dimension of the Item Specification Model is hierarchical. The Applications domain is more cognitively complex than Comprehension, which is in turn more complex than Computation and Knowledge. Following are three items taken from the Grade 4 assessment test. Each item measures an aspect of Number and Operation area of the Model, but each is from a different cell in the Domain dimension of the Item Specification Model:

(26) Add: $\begin{array}{r} 185 \\ +\ 412 \\ \hline \end{array}$

(45) The 2 in 2645 means:

2 hundreds .... ☐
2 thousands .... ☐
2 ones .... ☐
2 millions .... ☐
I don't know .... ☐

(53) On Monday, 185 people saw the morning whale shows and 412 people saw the afternoon whale shows. How many people saw the whale shows that day?

597 .... ☐
697 .... ☐
327 .... ☐
373 .... ☐
I don't know.. ☐

Item 26 belongs to the Computation and Knowledge domain, Item 45 to the Comprehension domain, and Item 53 to the Applications domain of Number and Operation content area. It should be noted that in order to solve Item 53, 185 and 412 must be added. This is the same computation as required in Item 26.

The Item Specification Model for the Mathematics Assessment is a 3 x 4 x 3 "cube": three grades (4, 8 and 12), four major mathematics content areas (Number and Operation, Measurement, Geometry, and Algebraic Concepts), and three domains (Computation and Knowledge, Comprehension, and Applications). The essential idea of the model is that the objectives and test items for the Mathematics Assessment can be classified in three ways: by grade, by content area, and by domain.

The model, as simple as it is, emphasizes the complexity of outcomes of mathematics learning. Many important areas of mathematics are not included, and no mention is made of attitudes toward mathematics. In this assessment, concern was limited strictly to cognitive outcomes. It is also true that although the model contains thirty-six cells, some of them are empty. For example, no attempt was made at the Grade/Year 4 level to test the area of Geometry, and the Algebraic Concepts domain at that level included only two graphing items.

2.2 Process of Development of Domain and Objectives

Much attention has been given recently to the importance of stating objectives for education. Books on teaching methods stress educational objectives, teacher-training courses typically have a requirement that lesson plans prepared by student teachers include a statement of objectives, and the mathematics textbooks used in the schools of B.C. all include statements of objectives for lessons or units in their teachers' editions. In similar fashion, a set of specific objectives corresponding to the domains discussed in the previous section was developed for use in the Mathematics Assessment. This set of objectives went through a very lengthy process of review and revision. Each objective generated was studied by the Contract Team, and the Management Committee. The penultimate version of the set of objectives was then submitted to four Review Panels for review and revision.

2.2.1 Review Panels

Four Review Panels were organized to afford people who were not involved in the creation of the objectives an opportunity of examining and proposing amendments to the objectives before the student tests were developed. The panels met with representatives of the assessment program to discuss the objectives and to seek to improve them.

The members of each Review Panel were chosen by the Learning Assessment Branch from a list of teachers most of whom had been identified by their district superintendents as being highly qualified in the field of mathematics, school trustees nominated by the Ministry of Education, and lay people who were identified in several ways, but mainly by school district superintendents listing people active in their communities. The basic make-up of each of the four mathematics Review Panels is presented in Table 2-1.

Table 2-1

Review Panel Members

Richmond	Haney	Castlegar	Victoria
11 Teachers	11 Teachers	13 Teachers	11 Teachers
1 Trustee	3 Supervisors	3 Lay persons	2 Principals
1 Supervisor	1 Principal	3 Supervisors	3 Lay persons
1 Lay person	4 Lay persons		2 Trustees
1 Administrator	2 Trustees		1 Teacher Educator

Each member of the Review Panels was sent a copy of the objectives for the Mathematics Assessment. Accompanying each objective was an example item that could be used to measure the objective. Before coming to the all-day meeting, each panel member was asked to examine and consider these objectives, to make suggestions regarding the possible uses and methods of dissemination of the information gathered, to suggest other types of information they would like to see gathered, and to propose ways in which such information could be collected by the Mathematics Assessment Program.

The meeting of each Review Panel began with the entire group discussing the Item Specification Model and commenting on each dimension and each category of each dimension. The Review Panel and assessment representatives then divided into three subgroups, one for each of three grade levels involved in the assessment. Each subgroup discussed the objectives for its grade level. When the discussion was completed the entire group reconvened and each subgroup reported the results of its discussion to the entire group. The Review Panel then made its final critique and the results were reported to the assessment group.

Two meetings were also held with the B.C. Mathematics Curriculum Revision Committee. The meetings were organized in a manner similar to the Review Panels except that the Revision Committee did not subdivide to examine each grade level. The committee as a whole considered the entire set of objectives.

Additional feedback concerning the objectives was obtained by having the objectives published in *Vector* (Kelleher, *et al,* 1976), the journal of the B.C. Association of Mathematics Teachers; and by discussing the objectives at the Summer Mathematics Conference of the B.C.A.M.T., at the Northwest Mathematics Conference, and at several professional day meetings of school districts.

The final version of the objectives, organized by grade level and domain, are presented in Tables 2-2 through 2-4. The right hand column in each of the three tables gives the number of items on the assessment instrument used to measure mastery of the accompanying objective.

Table 2-2

Domains and Objectives for Grade/Year 4

DOMAIN	OBJECTIVE	NUMBER OF ITEMS
1. Computation and Knowledge	1.1 Mastery of Number Facts	24
	1.2 Addition of Whole Numbers	5
	1.3 Subtraction of Whole Numbers	5
	1.4 Knowledge of Notation and Terminology	6
2. Comprehension	2.1 Understanding of Place Value Concepts	6
	2.2 Understanding of Number Properties	4
	2.3 Understanding of Measurement Concepts	5
	2.4 Understanding of Fraction Concepts	2
3. Applications	3.1 Solve Computational Problems	6
	3.2 Solve Practical Problems	6

The Grade/Year 4 Mathematics Assessment instrument contained sixty-nine items measuring mastery of ten objectives. The data in Table 2-2 show that the major emphasis in this assessment was in the Computation and Knowledge domain. Of the forty items in this domain, twenty-four were used to assess the Mastery of Number Facts objective. These items took the form of six number facts for each of addition, subtraction, multiplication, and division. In addition to the number fact items, there were ten addition and subtraction exercises requiring use of the algorithms.

In the Comprehension domain the emphasis was still on numbers, in particular understanding place value concepts and number properties. There were five items on measurement and two on fraction concepts. The Applications domain was evenly divided between computational problems and problems termed practical: i.e. working with time, money, graphs.

Several cells in the Item Specification Model were not tested at the Grade/Year 4 level. Such exclusions occurred for two main reasons: either the content was not part of the Grades 1 - 3 curriculum or the material could not be adequately assessed by means of a paper and pencil test. For example, in the primary grades very little is done with the algorithms for multiplication and division. Certain sets of numbers, for example, decimals, are not presented in the primary grades.

Geometry, on the other hand, is discussed in Grades 1 - 3, but is not listed among the objectives for the Grade 4 Mathematics Assessment.

The geometry instruction in the primary grades is based upon the manipulation of concrete objects. The two geometry objectives for Grade 3, listed in the Curriculum Guide are as follows:

> The student constructs simple geometric models of solids and plane shapes.
>
> The student recognizes axis of symmetry from experiences with concrete materials.

Given that the assessment instrument was a paper and pencil test, the geometry objectives could not be included on the Grade 4 mathematics assessment.

Table 2-3 contains the domains, objectives, and the number of items per objective for the Grade 8 Mathematics Assessment instrument. The test contained sixty items measuring acquisition of twelve objectives.

Table 2-3

Domains and Objectives for Grade 8

DOMAIN	OBJECTIVE	NUMBER OF ITEMS
1. Computation and Knowledge	1.1 Computation with Whole Numbers	5
	1.2 Computation with Rational Numbers in Fraction Form	4
	1.3 Computation with Rational Numbers in Decimal Form	5
	1.4 Knowledge of Notation and Terminology	9
	1.5 Knowledge of Geometric Facts	4
	1.6 Equivalent Forms of Rational Numbers	5
2. Comprehension	2.1 Comprehension of Number Concepts	6
	2.2 Comprehension of Measurement Concepts	5
	2.3 Comprehension of Geometric Concepts	4
	2.4 Comprehension of Algebraic Concepts	3
3. Applications	3.1 Solve Problems involving Operations with Whole Numbers, Fractions, Decimals, and Percent	7
	3.2 Solve Problems involving Geometry and Measurement	3

The emphasis in the Computation and Knowledge domain for Grade 8 is on computation with different sets of numbers. Assessment of knowledge of geometric facts in included in the Grade 8 assessment. Geometry, in fact, is a factor in each domain for the Grade 8 assessment. All four content areas are assessed in the Comprehension domain, but with varying numbers of items. The emphasis in the Applications domain is on solving problems using different sets of numbers and numbers in different forms.

A comparison of Tables 2-2 and 2-3 shows that the major differences between the Grade 4 and 8 levels are found in the inclusion of geometric concepts and in the shift in emphasis in the Computation and Knowledge domain in the Grade 8 test. By Grade 8, computation includes all four basic operations with whole numbers, rational numbers in fraction form, and rational numbers in decimal form.

Table 2-4 lists the domains, objectives, and the number of items per objective for the Grade 12 Mathematics Assessment. The test contained seventy-two items measuring acquisition of eleven objectives.

Table 2-4

Domains and Objectives for Grade 12

DOMAIN	OBJECTIVE	NUMBER OF ITEMS
1. Computation and Knowledge	1.1 Computation with Rational Numbers in Fraction Form	4
	1.2 Computation with Rational Numbers in Decimal Form	5
	1.3 Knowledge of Notation and Terminology	14
	1.4 Knowledge of Other Algorithms	7
2. Comprehension	2.1 Comprehension of Number Concepts	6
	2.2 Comprehension of Measurement Concepts	5
	2.3 Comprehension of Geometric Concepts	4
	2.4 Comprehension of Algebraic Concepts	9
3. Applications	3.1 Solve Problems Involving Operations with Whole Numbers, Fractions, Decimals, and Percent	9
	3.2 Solve Problems Involving Geometry and Measurement	7
	3.3 Solve Algebraic Problems	2

In the Computation and Knowledge domain, the Knowledge of Notation and Terminology objective involves several more items than were required for Grade 8. Computation with Rational Numbers is still included, but Knowledge of Other Algorithms has been added. The Comprehension domain for Grade 12 looks very similar to that for Grade 8 except for Comprehension of Algebraic Concepts which assumes a more important position in Grade 12 than it had in Grade 8. The Applications domain is most comprehensive for Grade 12, involving eighteen items. Algebraic problems are presented for the first time and the other two categories have more items than in Grade 8, particularly geometry and measurement problems.

The Grade 8 and 12 objectives have many similarities. In fact, many of the items on the Grade 8 mathematics assessment were repeated for the Grade 12 assessment. The common items were used for comparison purposes.

The set of Grade 12 objectives, unlike Grade 8, includes no reference to computation with whole numbers; it is replaced by knowledge of other algorithms. The Grade 12 set of objectives reflects a much stronger emphasis on the Algebraic Concepts content area and the Applications domain.

The distribution of items organized by grade and content area is presented in Table 2-5 below. Since the tests were of differing lengths (Grade 4 - 69 items, Grade 8 - 60 items, Grade 12 - 72 items), the data presented in Table 2-5 are percentages. The fact that some of the rows in the table do not have a total of 100% is due to the effect of rounding each percentage to the nearest whole number.

Table 2-5

Percent of Items in Each Content Area by Grade

	Content Area			
Grade	Number and Operation	Measurement	Geometry	Algebraic Concepts
4	78	17	0	3
8	63	17	12	8
12	50	15	15	19

The data in Table 2-5 show a decreasing emphasis on the Number and Operations content area as grade level increases, and an increasing emphasis on the Algebraic Concepts content area. The Measurement content area has a very consistent emphasis as does Geometry in Grades 8 and 12.

The distribution of items organized by domain and grade level is presented in Table 2-6. As with Table 2-5, the data in Table 2-6 are percentages.

Table 2-6

Percent of Items in Each Domain by Grade

	Domain		
Grade	Computation and Knowledge	Comprehension	Applications
4	58	25	17
8	53	30	17
12	42	33	25

The data in Table 2-6 show several patterns. The percent of items decreases as the level of complexity of cognitive behavior increases. Within a domain the emphasis remains rather stable for the three grade levels with a slight decrease in the Computation and Knowledge domain as grade level increases and slight increases in Comprehension and Applications domains.

The data presented in Tables 2-5 and 2-6 reflect the goals of the B.C. Mathematics Assessment program. The major goal was to assess student's performance on some of the essential skills of mathematics which are predominantly number and operation oriented. Although the assessment examined students' knowledge and computational abilities, it did not ignore the cognitively more complex domains.

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Chapter 3

GRADE/YEAR 4: RESULTS, INTERPRETATION, AND RECOMMENDATIONS

This chapter contains a discussion of the Grade/Year 4 results for each item and for each objective assessed. A limited number of items from the assessment instrument are presented and discussed as illustrative examples; however, because of space limitations, it was not possible to discuss each individual item in detail in this chapter. A companion volume in the series, Report Number 3: Technical Report, contains summary information about each item on each of the three tests. Copies of the Technical Report may be obtained from the Learning Assessment Branch, Ministry of Education.

3.1 Description of the Test

The Grade/Year 4 test contained sixty-nine items designed to assess students' mastery of ten objectives of the primary grade mathematics curriculum which were grouped into the three domains. In addition to these mathematics items, the test contained thirteen background information items which students were asked to complete before taking the test.

Items 1 - 39 on the Grade/Year 4 test were open-ended. Items 40 - 69 were multiple-choice exercises. Students responded to the test items in the test booklet itself by either writing the answer for open-ended exercises or marking their choice of answer with an "x" for the multiple-choice items. The information from the booklets was then keypunched into machine-readable format.

One and one-half hours were alloted for the test: thirty minutes for instructions, distribution and collection of the test booklets and completion of the background information items, and sixty minutes for completion of the test itself. The background information items were administered first. Teachers administering the test were asked to read each of these items to their students and to assist them in completing the items correctly.

The test itself was divided into three parts. Part 1 was timed and consisted of twenty-four basic fact items, six for each of the operations of addition, subtraction, multiplication, and division. Students were given four minutes to complete this portion of the test. Parts 2 and 3 were not speed tests; students were given one hour to do the items on this portion of the test. Part 2 consisted of fifteen items dealing with computational skills. These were open-ended items. Part 3 contained thirty multiple-choice exercises.

3.2 Description of the Population

The Grade/Year 4 Mathematics Assessment was designed for all students enrolled in their fourth year of schooling. According to statistics released by the Ministry of Education, 36 540 children were enrolled at that level as of 28 February 1977. The Mathematics Assessment test was written by 35 277 students, or 96.5% of the total. This falls well within the normal range of attendance at this grade level. The best information available from the Ministry of Education is that 6% absenteeism is the amount that may be expected of any given day at the elementary school level.

3.2.1 Distribution by Sex

Approximately one thousand more boys than girls took part in the assessment. Overall, as is shown in Table 3-1, 51.1% of the respondents were boys while 48.3% were girls. This slight preponderance of boys was repeated at the Grade 8 level, but reversed at the Grade 12 level.

Table 3-1
Grade/Year 4: Sex of Respondents

Sex	Frequency	Percent
Male	18 046	51.1
Female	17 053	48.3
No response	175	0.4
Multiple response	3	0.0

3.2.2 Age

The assessment instrument was administered during the month of March 1977. At that time, students who were age 6 at the time of their enrollment in school should have been either 9 or 10 years old. The data presented in Table 3-2 show that the vast majority of students at the Grade/Year 4 level do fall within the normal range of ages expected.

Table 3-2
Grade/Year 4: Ages of Respondents

Age	Frequency	Percent
7 or younger	121	0.3
8	1 359	3.8
9	20 768	58.8
10	10 987	31.1
11	1 537	4.3
12 or older	149	0.4
No response	356	1.0

3.2.3 Number of Schools Attended

The results of this item attest to the high degree of mobility that exists among the families of British Columbia since the number of schools attended by a child is highly correlated with the number of residences in which the child has lived. Slightly more than 11% of students at the Grade/Year 4 level had at the time of this assessment already attended at least four schools since they enrolled in Grade 1. Less than half the population had been in only one school since the beginning of Grade 1.

Table 3-3
Grade/Year 4: Number of Schools Attended

Number	Frequency	Percent
1	15 694	44.4
2	10 021	28.4
3	4 944	14.0
4 or more	3 974	11.2
No response	388	1.0
Multiple response	256	0.7

3.2.4 National Origin and Languages Spoken

The data obtained regarding students' country of origin (see Table 3-4) must be interpreted with caution because of the large number of children (over 13% of the total) who failed to respond. This lack of response may be due to the students not knowing in which country they were born. In any event, the data indicate that approximately 75% of the students enrolled in Grade/Year 4 are of Canadian origin.

Table 3-4
Grade/Year 4: Country of Origin

Country	Frequency	Percent
Canada	26 215	75.3
Other	4 389	12.4
No response	4 661	13.2
Multiple response	12	0.0

Students were asked to respond "Yes" or "No" to the question "Is English the language usually spoken in your home?" The results presented in Table 3-5 indicate that approximately 15% of the Children at this level have some language other than English as a first language. This compares to a rate of approximately 10% at the Grade 8 and 12 levels as determined by the Reading Assessment which was administered during the same week as the Mathematics Assessment.

Table 3-5
Grade/Year 4: Language Spoken at Home

Language	Frequency	Percent
English	29 596	83.8
Other	5 235	14.8
No response	394	1.1
Multiple response	52	0.1

3.2.5 Television Viewing Patterns

In response to the question "About how many hours of television do you watch on an average day during the week?", approximately one child in every three at the Grade/Year 4 level indicated watching five or more hours of television per day during the week. The same question was asked of Grade 8 and 12 students on the Reading Assessment instruments, and their results indicate that about 25% of Grade 8 and 7% of Grade 12 students spend that much time viewing television.

Table 3-6
Grade/Year 4: Hours of Television Watched Per Day

Time	Frequency	Percent
Usually none	1 396	3.9
Less than 1 hour	1 383	3.9
About 1 hour	3 013	8.5
About 2 hours	5 843	16.5
About 3 hours	6 791	19.2
About 4 hours	5 949	16.8
5 hours or more	10 902	30.9

These data mean that 30% of our children are spending at least as much time watching television on a weekday as they are spending in school. A great deal of research is needed if we are to understand and deal with the implications of this activity which consumes an enormous part of our students' out-of-school time. Some recent findings such as those reported by Language B.C., indicate that watching an excessive amount of television is associated with poor performance in reading.

3.2.6 Hand-Held Calculators

The hand-held calculator is the latest in a series of teaching and learning aids which seem to hold promise for the improvement of students' achievement in and understanding of mathematics. A good deal of research interest in the field of Mathematics Education is currently focused upon an examination of the effect of the use of hand-held calculators in the mathematics classroom.

As part of the Mathematics Assessment, students at all three levels involved, 4, 8 and 12, were asked several questions concerning their use of hand-held calculators. Their responses to these questions are summarized in Table 3-7.

Table 3-7
Use of Hand-Held Calculators

	Responses in Percent		
Category of Use	Grade 4	Grade 8	Grade 12
Have never used a calculator	23.3	question not asked	
Have used a calculator at home	49.9	35.1	50.6
Have used a calculator for homework	12.8	28.9	55.7
Have used a calculator in school	3.0	10.1	51.2

The fact that only 3% of children in Grade/Year 4 have used a calculator in school may be indicative of the fact that educators are not convinced of the advisability of using calculators with students at this level.

3.3 Test Results: Computation and Knowledge Domain

As discussed in Chapter 2, the sixty-nine items on the Grade/Year 4 test were divided among three domains: Computation and Knowledge (40 items), Comprehension (17 items), and Application (12 items). Each *domain* was sub-divided into a number of *objectives* and *items* were generated to measure mastery of the objectives. In this section, the results from the Computation and Knowledge domain are discussed, objective by objective. For each objective, the following information is provided in tables: the number of the item or items from the test, the percent of students who obtained the correct answer, and the judgment of the Interpretation Panel concerning the acceptability of the result.

3.3.1 Mastery of Basic Facts

The term 'basic facts' refers to sums and products of pairs of single digit whole numbers, as well as to their corresponding differences and quotients. Thus 9 + 7 = 16, 14 - 6 = 8, 6 x 4 = 24, and 48 ÷ 6 = 8 are basic facts, whereas 11 + 5 = 16, 14 - 3 = 11, 12 x 7 = 84, and 45 ÷ 3 = 15 are not.

According to the current Curriculum Guide for Mathematics, students are expected to have mastered all of the basic facts for addition and subtraction by the end of Grade 3, as well as those basic facts for multiplication and division with products or dividends less than 50. To assess attainment of this goal, students were given four minutes to respond to twenty-four basic fact items, six items for each operation. The results obtained are presented in table 3-8.

Table 3-8
Grade/Year 4 Results (N = 35 277)
Objective: Mastery of Basic Facts (mean = 88.3%)

Item Nos.	Operation	Percent Correct	Panel Judgment
1 - 6	Addition	96.6	Strength
7 - 12	Subtraction	92.6	Very Satisfactory
13 - 18	Multiplication	88.2	Very Satisfactory
19 - 21	Division	79.7	Satisfactory
22 - 24	Division	73.7	Marginally Satisfactory

The Panel members were pleased with the results for the first three operations, but less so with the division results. They said that the lower performance in division might be due to several factors such as the difficulty of division, or the placing of the division items last. Some Panel members expressed concern about the emphasis on division facts in the primary grades, since many children still require concrete materials as an aid to solution.

The facts that division is the most difficult of the four basic operations and that it is the last of the four operations to be introduced are probably among the reasons for the lower performance of students on the division basic fact items. It is also possible that, despite the fact that students were given ten seconds per item on this part of the test, many of them failed to get as far as the division items. The average percent of no response went from virtually zero on the six addition items to 2% for subtraction 6% for multiplication and about 18% for division. It should be noted, however, that it is not possible to tell from these data what factor or factors were the actual cause of the lower performance in division.

3.3.2 Addition of Whole Numbers

The test contained five items to assess students' ability to find the sum of two or more whole numbers. Four of the five items required students to regroup (carry) at least once.

Table 3-9
Grade/Year 4 Results (N = 35 277)
Objective: Addition of Whole Numbers (mean = 87.0%)

Item No.	Percent Correct	Panel Judgment
26	92	Very Satisfactory
28	80	Satisfactory
29	90	Very Satisfactory
32	84	Very Satisfactory
38	89	Very Satisfactory

The Interpretation Panel was very satisfied with these results. They expressed the opinion that Item 28 could have been classified with the Applications items rather than the Computation and Knowledge ones.

Item 28 and the response rates expressed as percents are shown in Figure 3-1.

(28) Add:

$ 3.06
10.00
9.14
+ 5.10

Responses	Percent
$2730	52%*
2730	28%
$1730	2%
1730	2%
Other	14%
No response	2%

Figure 3-1
Grade/Year 4: Item 28

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*The correct answers are underlined.

The results for this item show that 80% of students obtained the correct numerical answer but that only 52% included the dollar sign. Unfortunately, there is no data available concerning students' inclusion or non-inclusion of the decimal point in their answer. This piece of information was not keypunched.

Overall, the students' performance on the addition items was commendable. There is a considerable amount of evidence that a large percentage of students are capable of and do learn how to find the sum of two or more whole numbers with a high degree of success.

3.3.3 Subtraction of Whole Numbers

As in the case of addition, the test contained five items dealing with subtraction of whole numbers. Of these, three items required students to regroup (borrow) at least once.

Table 3-10
Grade/Year 4 Results (N = 35 277)
Objective: Subtraction of Whole Numbers (mean = 74.8%)

Item No.	Percent Correct	Panel Judgment
25	90	Very Satisfactory
30	72	Marginally Satisfactory
33	87	Satisfactory
36	56	Weakness
39	69	Marginally Satisfactory

The Panel found the results on subtraction with regrouping items to be rather low. They attributed this performance to the difficulty of the place value concepts involved, to the difficulty of the items, or to the insufficient availability of manipulative materials for teachers and for students.

Item 36 involves regrouping when there is a zero in the minuend, the most difficult kind of subtraction exercise. The actual item and the results are displayed in Figure 3-2.

Learning to use the subtraction algorithm correctly requires a considerable degree of understanding of our decimal numeration system. Many students fail to gain such an understanding and, as the Interpretation Panel has stated, teachers need to have a quantity of appropriate manipulative devices available both for teaching place value concepts and for developing students' abilities to use algorithms.

(36) Subtract:

$$\begin{array}{r} 1054 \\ -\ 865 \\ \hline \end{array}$$

Responses	
189	56%
1811	6%
1189	2%
289	4%
199	3%
89	3%
889	2%
1011	1%
179	1%
Other	18%
No response	4%

Figure 3-2
Grade/Year 4: Item 36

It is worth noting here that the most frequent incorrect response to Item 36 is 1811 which is obtained by always subtracting the lesser of the two numbers from the greater, thereby eliminating the need for any regrouping. A student's train of thought here might proceed as follows: "4 from 5 is 1, 5 from 6 is 1, 0 from 8 is 8, nothing from 1 is 1." It seems clear that a student who can begin with one number (1054), subtract a second number (865), and end up with a number larger than he started with (1811) lacks an understanding of many of the factors involved in the operation of subtraction.

In summary, although the results of the subtraction items are basically satisfactory, there appears to be a weakness when regrouping is required. Such weaknesses are most apparent when one of more of the digits in the minuend is zero.

Recommendation 3-1: *Teachers of mathematics should have access to and make liberal use of appropriate manipulative devices for the teaching of place value concepts and of operations on numbers. This recommendation is equally important at both the primary and the intermediate levels.*

Recommendation 3-2: *Persons involved in the pre-service or in-service education of teachers are urged to emphasize the importance of having students make use of manipulative devices as models for mathematical concepts and skills at all times, but particularly when such concepts and skills are being introduced for the first time.*

3.3.4 Knowledge of Notation and Terminology

At every level, students are expected to be familiar with certain commonly used mathematical terms as well as with the symbols used to represent various operations, relationships, and quantities. Six items on the Grade/Year 4 test were designed to assess students' familiarity with such notation and terminology.

Table 3-11
Grade/Year 4 Results (N = 35 277)
Objective: Knowledge of Notation and Terminology (mean = 74.8%)

Item No.	Topic	Percent Correct	Panel Judgment
48	<, >, =	76	Very Satisfactory
49	odd nos.	67	Satisfactory
51	using $	88	Satisfactory
56	telling time	88	Very Satisfactory
57	reading temp.	81	Very Satisfactory
63	metres	49	Marginally Satisfactory

The Panel felt that the overall performance here was satisfactory. They expressed the opinion that the symbols of inequality (Item 48) and the definition of odd numbers (Item 49) were relatively unimportant, and that Item 63 was quite difficult.

Item 63 was one of several items dealing with the metric system of measurement. As is shown in Figure 3-3, it was a multiple-choice item rather than an open-ended one.

(63) 5 metres is the same length as:

Response	Percent
50 centimetres	27
500 centimetres	49
50 millimetres	10
500 millimetres	4
I don't know	7
No response	3

Figure 3-3
Grade/Year 4: Item 63

Item 63 and four others were used on all three tests to assess familiarity with the metric system of measurement, and the Grade/Year 4 students obviously found Item 63 difficult. This was not completely unexpected, and one of the reasons that the item was included on the level 4 test was to chart the differences in performance on this item among the three populations tested. At the

Grade/Year 4 level it is more important that students measure and gain concrete experiences than it is that they learn to convert units within the metric system.

In general, knowledge of notation and terminology is relatively unimportant as compared with other aspects of the mathematics curriculum. It is more important to be able to find the difference of two numbers than it is to know that the two numbers used are called the minuend and the subtrahend. On the other hand, teachers must use mathematical terminology and symbolism in their teaching and it is important that students understand the terms and symbols being used. Perhaps a minimal list of terms and symbols that all students should be familiar with needs to be developed and made part of the mathematics curriculum.

Recommendation 3-3: Educators should attempt to identify a list of mathematical terms which students should learn as well as a teaching sequence for developing such vocabulary. This list and sequences should take into account the developmental nature of the acquisition of meaningful mathematical vocabulary.

3.4 Test Results: Comprehension Domain

3.4.1 Understanding of Place Value Concepts

Six items on the Grade/Year 4 test dealt with understanding of place value or numeration concepts. One of these was an open-ended item (Item 35) while the remainder were multiple-choice exercises.

Table 3-12
Grade/Year 4 Results (N = 35 277)
Objective: Understanding of Place Value Concepts (mean = 78.2%)

Item No.	Topic	Percent Correct	Panel Judgment
35	Multiplying by 100	61	Marginally Satisfactory
44	Counting by tens	91	Very Satisfactory
45	Value of digit	88	Very Satisfactory
46	Rounding off	59	Marginally Satisfactory
47	Largest number	79	Marginally Satisfactory
50	Number names	91	Very Satisfactory

The Panel was of the opinion that results on counting by tens (Item 44) and writing numbers (Item 50) were very satisfactory, as was naming 'places' (Item 45). However, performance was less satisfactory on identifying the largest number (Item 47), and in rounding off (Item 46).

The children's performance on Item 46 requires some comment. The distribution of responses to that item are shown in Figure 3-4:

(46) Round off 43 to the nearest ten.

Response	Percent
30	8
50	11
40	59
44	14
I don't know	8
No response	1

Figure 3-4
Grade/Year 4: Item 46

It is generally agreed that the skill of estimation is of great importance in mathematics. A pupil who is able to estimate can tell whether or not his answer is reasonable. To cite an example discussed in the previous section, a student who knew how to estimate and who did so would not be satisfied with 1811 as an answer to Item 36:

(36) Subtract:

$$\begin{array}{r} 1054 \\ -\ 865 \\ \hline \end{array}$$

The ability to round off numbers is an integral part of the skill of estimating, and the results obtained on Item 46 should be a cause of some concern to teachers.

The Interpretation Panel felt that the students' less than satisfactory performace on this item might be partially due to a lack of familiarity with the term 'round off', as well as to a lack of emphasis on this topic in the curriculum. To the degree that lack of familiarity with the terminology was a contributing factor to the students' performance, the importance of knowledge of terminology is illustrated. The term "round off" is the correct term and there is no concise and generally used expression which conveys the same mathematical meaning.

Recommendation 3-4: The importance of place value skills and concepts, including estimation, cannot be overemphasized. Teachers and those involved in teacher education should stress the necessity of develop-

ing understanding of place value concepts by building upon a foundation of concrete learning experience.

3.4.2 Understanding of Number Properties

Students' performance on this set of four items was most encouraging and, as can be seen from the ratings, the Interpretation Panel was pleased with these results.

Table 3-13
Grade/Year 4 Results (N = 35 277)
Objective: Understanding of Number Properties (mean = 90%)

Item No.	Topic	Percent Correct	Panel Judgment
27	Multiplying by zero	90	Very Satisfactory
31	Missing minuend	81	Very Satisfactory
34	Adding zero	95	Strength
37	Multiplying by one	95	Strength

Items 27, 34, and 37 dealt with the roles of the numbers 0 and 1 in addition and multiplication. The results show that almost all students are familiar with these important concepts.

The Panel commented that the overall performance here was one of strength. They said that although Item 31 was measuring the idea that subtraction is the inverse of addition, it is not clear that this was the approach used by the children. Item 31 required students to solve the equation

$$\_\_ - 3 = 7$$

This is the most difficult type of additive-subtractive open sentence to solve with respect to the position of the placeholder. Thirteen percent of the students chose four as their answer to this open-ended item.

3.4.3 Understanding of Measurement Concepts

Of the five items in this part of the test, four measured the ability to choose the appropriate metric measure in situations involving length, mass, capacity, and temperature. The fifth item, Item 59, dealt with the concept of area.

Table 3-14
Grade/Year 4 Results (N = 35 277)
Objective: Understanding of Measurement Concepts (mean = 54%)

Item No.	Topic	Percent Correct	Panel Judgment
59	Area	61	Satisfactory
61	Length	81	Satisfactory
62	Capacity	67	Marginally Satisfactory
64	Mass	25	Marginally Satisfactory
65	Temperature	32	Weakness

The Panelists stated that Item 59 dealt with area and the students' performance was deemed satisfactory given the sophistication of the concept of area and the limitations of paper-and-pencil tests. The students' performance of the metric measurement items, however, was generally disappointing.

According to the Curriculum Guide for Mathematics, these students have been taught the metric system of measurement and only the metric system since they entered school. In spite of this, only 32% chose the appropriate temperature for a sunny summer day (25° Celsius) and only 25% were able to select the appropriate mass[*] for a ten-year-old boy (35 Kilograms). On a third item, 67% of the children were able to pick the appropriate capacity of a milk jug.

In each of these items, only one choice was the reasonable one. The other three were clearly incorrect to anyone familiar with the units involved. The three incorrect choices of temperature were 5°C, 55°C, and 85°C; the three incorrect masses were 35 grams, 75 grams, and 75 Kilograms; the incorrect capacities were 1 millilitre, 10 millilitres and 100 litres.

The Interpretation Panel felt that Item 62 should have made use of the term "carton of milk" rather than "jug of milk". This issue was discussed during the development of the test, and since milk was then being sold in one- and three-*quart* cartons, it was felt the term "jug" would cause less confusion.

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[*] The word 'mass' was not used on the test. Although technically incorrect, the stem was worded as follows:
"A ten-year-old boy is likely to weigh: . ."
It was deemed more advisable to run the risk of being criticized for using the familiar word 'weigh' than to use the decidedly unfamiliar, yet correct, term 'mass'.

Over the past several years, a great number of in-service workshops have been conducted throughout the province at both the school and district level. During the same period, schools have purchased metric measuring devices and teaching aids. However, results indicate there is undoubtedly room for improvement as regards the teaching of the metric system of measurement at this level.

Recommendation 3-5: *The Ministry of Education and local school districts should cooperate in ensuring that materials for teaching the metric system are available in all schools.*

Recommendation 3-6: *Follow-up workshops and conferences designed to emphasize the best methods, materials, and techniques to be used in teaching measurement should be provided. Such professional development workshops should emphasize the importance of students' obtaining "hands on" experience in measuring in order to facilitate the development of their ability to "THINK METRIC".*

3.4.4 Understanding of Fraction Concepts

Only two test items concerned the development of fraction concepts. Not a great deal of emphasis is given or should be given to fractions in the primary grades, but the Curriculum Guide does call for an understanding of unit fractions (i.e., fractions with numerators of 1) both as part of a whole and as part of a set.

Table 3-15
Grade/Year 4 Results (N = 35 277)
Objective: Understanding of Fraction Concepts (mean = 57.0%)

Item No.	Topic	Percent Correct	Panel Judgment
58	Part of a set	60	Marginally Satisfactory
60	Part of a whole	54	Weakness

The Panel found these results disappointing. They said that Item 58 may have been somewhat misleading but it still was a relatively weak performance.

The most pervasive model for fractions is the part of a whole model in which a 'whole' is divided into a number of congruent, contiguous parts. For example, a candy bar is divided into four congruent parts, each representing one fourth of the whole candy bar. Item 60 (see Figure 3-5) assessed students' understanding of this fraction model.

(60) Which box is one-fifth ($\frac{1}{5}$) shaded? No Response: 1

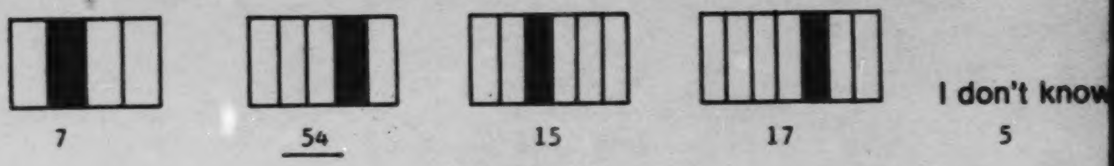


Figure 3-5
Grade/Year 4: Item 60

Note that 17% chose the situation where the fifth rectanglar region was shaded and that another 15% chose the response where one region was shaded and five were not.

Many children in the intermediate grades are unable to learn or to remember algorithms for computing with fractions. One of the underlying causes of such a disability is frequently found to be a lack of understanding of basic fraction concepts. The results obtained from these two items seem to indicate that a substantial protion of students in Grade/Year 4 do not have an adequate grasp of the most fundamental fraction concepts.

Teachers as well as curriculum developers must realize that fraction concepts, even the most elementary ones, are rather sophisticated and that a great many students find them difficult. It seems clear that both models for fractions which have been mentioned here need emphasis. It may also be the case that these concepts are being introduced to children prematurely. Perhaps if these concepts were not introduced in the primary grades at all, but instead delayed until the children were somewhat more mature, students might comprehend them better and develop fewer misconceptions.

Recommendation 3-7: Educators, curriculum developers, and educational researchers should address the problem of the optimum time for introducing fraction concepts in the mathematics classroom bearing in mind both the children's development level and the sophistication of the ideas involved in these concepts. When introductory fraction concepts are being developed, both models, part of a whole and part of a set, should be emphasized.

3.5 Test Results: Applications Domain

The Applications domain, as described in Chapter 2, includes the following categories of cognitive behaviour: ability to solve routine problems, ability to analyze data, and ability to recognize patterns. For the Grade/Year 4 test, the Applications items were collected into two groupings or objectives. Items which were considered to deal with application within the day-to-day experience of the children were categorized as "practical", other problem situations were described as being "computational" in nature.

3.5.1 Solves Practical Problems

The six items in this grouping dealt with applications of the concepts of time (Items 40 and 42), money(Items 43 and 55), and interpreting graphs (Items 68 and 69). The results, as shown in Table 3-16, are quite encouraging.

Table 3-16
Grade/Year 4 Results (N = 35 277)
Objective: Solve Practical Problems (mean = 78.0%)

Item No.	Topic	Percent Correct	Interpretation
40	Time	77	Satisfactory
42	Time	49	Marginally Satisfactory
43	Money	82	Satisfactory
55	Money	86	Very Satisfactory
68	Graphs	92	Strength
69	Graphs	82	Very Satisfactory

The Panelists stated that all areas except that tested by Item 42 were at least satisfactory. They felt that perhaps the content of Item 42 was not relevant to children of this age. They recommended that materials should be available in classrooms to provide practice in practical problem solving.

In Item 42, students were asked to find the elapsed time between 4:25 p.m. and 5:00 p.m. Twenty percent of the children subtracted 425 from 500 and selected 75 minutes as their response. It may be that students are not familiar with the notation 4:25 since that is not the way in which times are usually denoted in everyday usage.

Problem-solving represents the highest level of cognitive functioning, and these results indicate that a substantial proportion of children at the Grade/Year 4 level are learning to solve problems and are experiencing success in that endeavour.

It is important to bear in mind that developing the student's ability to apply the appropriate mathematical techniques in order to solve a given problem is one of the most important reasons for teaching and learning mathematics. There is no point in teaching children how to add, subtract, multiply, and divide numbers unless they also learn when to apply these operations. The results reported here indicate a fairly substantial degree of progress toward that goal has been attained at the Grade/Year 4 level insofar as "practical" applications are concerned.

Children require a great deal of practice in problem-solving techniques, and good teaching practice dictates that the problems assigned to children should be as interesting as possible. Problems based upon local places and happenings are more likely to motivate children than are problems out of a mathematics textbook. Teachers of mathematics at all levels would do well to set up collections of "real" problems for use with their classes.

Recommendation 3-8: *Teachers of mathematics should emphasize classroom, school, and local situations for developing "real" problem-solving experiences which will be relevant to their students.*

3.5.2 Solves Computational Problems

The exercises included under this heading are those usually termed "word problems" or "story problems". These are the types of problems typically found in school mathematics textbooks. A problem situation is described in words, and the student must decide what operation or operations are required in order to solve the problem, and then perform these operations correctly. The results obtained on the six items used to assess this objective are summarized in Table 3-17.

Table 3 - 17

Grade/Year 4 Results (N = 35 277)

Objective: Solve Computational Problems (mean = 64.7%)

Item No.	Percent Correct	Panel Judgement
41	79	Satisfactory
52	39	Satisfactory
53	88	Strength
54	60	Satisfactory
66	47	Satisfactory
67	75	Satisfactory

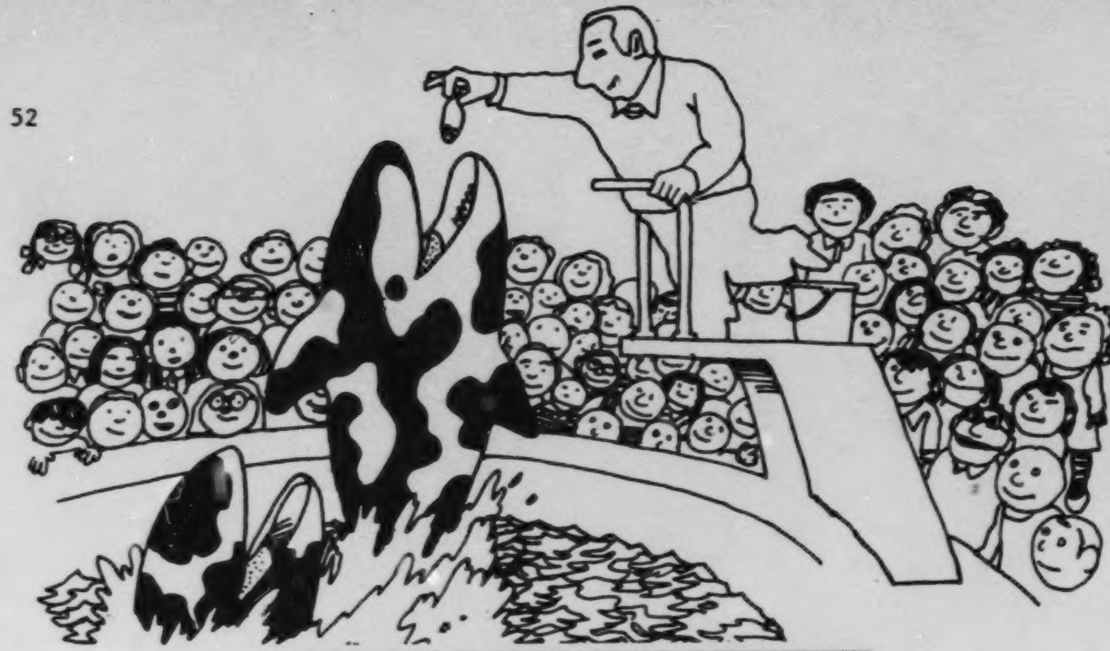
The Panel rated performance of all items satisfactory, except 53 which was a strength. The low percentage for 52 was considered satisfactory, as the group felt measurement rather than conversion was more important at this level. Items 53 and 26 involved the same computation and the percent correct on Item 53 was only 4% less than that on 26. Items 54, 66, 67 were satisfactory considering the complexity involved.

Because of the importance of problem-solving in the teaching and learning of mathematics, all six of the items for this objective are reproduced in Figures 3-6 through 3-8.

(41) **The roller coaster has 8 cars with 4 wheels on each car. How many wheels are there on the roller coaster?**

Response	%
12	12
2	1
32	79
24	4
I don't know	2
No response	1

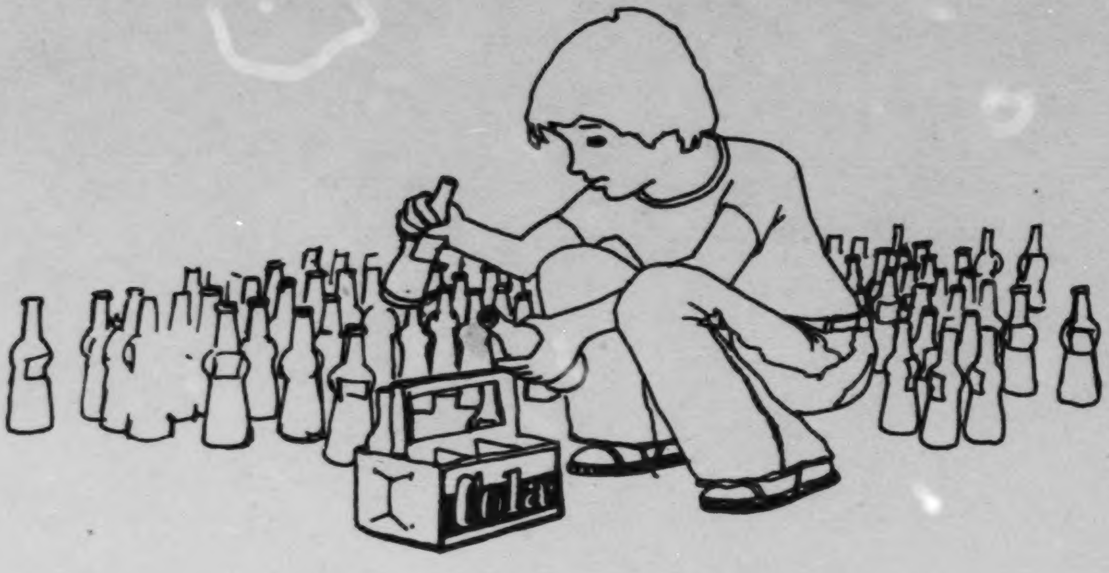
Figure 3 - 6: Grade/Year 4 - Item 41



Skana and Hyak are killer whales.
They live in the Vancouver Aquarium.
Here is Skana jumping to get a fish.

	Response	%
(52) Skana can jump 627 centimetres high. Hyak can jump 5 metres high. How much higher can Skana jump than Hyak?	127 centimetres	39
	622 centimetres	23
	22 centimetres	14
	632 centimetres	8
	I don't know	15
	No response	1
(53) On Monday, 185 people saw the morning whale shows and 412 people saw the afternoon whale shows. How many people saw the whale shows that day?	597	88
	697	4
	327	2
	373	2
	I don't know	3
	No response	1
(54) Yesterday, Skana ate a total of 98 fish in three meals. She ate 32 fish at the first meal and 25 fish at the second meal. How many fish did she eat for her third meal?	66	4
	41	60
	155	15
	57	12
	I don't know	7
	No response	1

Figure 3 - 7: Grade/Year 2 - Items 52, 53, 54



Sam has 51 pop bottles and 8 cartons. Each carton holds 6 bottles.

		Response	%
(66)	**If Sam fills all the cartons, how many bottles will be left over?**	6	8
		8	10
		3	47
		14	24
		I don't know	10
		No response	1
(67)	**Sam collected 30 of the bottles. His sister, Marie, collected the rest. How many bottles did Marie collect?**	18	4
		14	6
		21	75
		44	6
		I don't know	7
		No response	1

Figure 3 - 8: Grade/Year 3 - Items 66, 67.

In three cases, problem-solving items were paired with computation items involving the same numbers in order to obtain a measure of the extent to which presenting an item as a word problem affected the success rate. The data relative to that question are presented in Table 3-18.

Table 3 - 18

Grade Year 4 Results (N = 35 277)

Problem-Solving vs. Computation Items

Item number		Percent Correct		Required
P.S. *	Com. **	P.S. *	Com. **	Computation
41	16	79	86	4 x 8
52	33	39	87	627 - 500
53	26	88	92	185 + 412

* P.S. means problem-solving
** Com. means computation

In two of the three cases, Items 41 and 53, the comparison of results between the problem-solving and the computational items is excellent. There is a relatively low decrease in performace attributable to presenting the item as a word problem. It may be the case that reading difficulties account for much of the difference but another plausible explanation might be that some students do not know when to apply the operations which they have learned to perform. For example, 12% of the students found the sum 4 and 8 for Item 41 rather than finding the product.

The reasons for the great difference between the performance on Items 33 and 52 become more evident upon reading Item 52. Before students could solve this problem, they had first to write 5 metres as 500 centimetres. This particular skill was tested by Item 63 (See Figure 3-3), and only 49% of the children obtained a correct result. In that light, 39% on Item 52 is certainly a satisfactory performance at least.

Item 52 is an example of a multi-step problem, as are Items 54 and 66. Such problems are, of their nature, more difficult than one-step problems, and it is not at all surprising that the success rate on these problems is relatively low. When the test was constructed, certain items which were known to be difficult, including these three were deliberately included. It would be erroneous to assume that there is always a direct relationship between the percent correct on an item and the degree of acceptability of that result. For example, a success rate of 39% on Item 52 would certainly be preferable to a success rate of 75% on a basic fact item or on an item measuring attainment of a relatively simple skill.

As was the case with "practical" problem items, the results obtained on these six items are evidence that students at the Grade/Year 4 level are achieving satisfactorily insofar as problem-solving is concerned. Certainly there is room for improvement, but the findings of this assessment indicate that students at the Grade/Year 4 level have attained a reasonable degree of ability to cope with word problems in mathematics.

The Interpretation Panel expressed reservations about some of the art work used on the test, as well as about the use of the names of the killer whales at the Vancouver Aquarium in two of the problems. The decision to make extensive use of art work on the test was motivated by a desire to make the test booklet as appealing and interesting to children as possible. Similarly, it was felt that Skana and Hyak were names that were familiar to children in this province. These matters were thoroughly discussed and the results of the pilot testing, which was done in several locations across the province, did not indicate that children had any difficulty with either the art work or the vocabulary.

3.6 Grade/Year 4 Reporting Categories

Mathematics achievement is the end result of the coalescing of a great number of student-based factors, both extrinsic and intrinsic. Attributes inherent in the student, programmatic and curricular variables, as well as the effect of environmental variables such as teacher differences all contribute in varying and largely unknown degree to a given student's overall performance. Of the fairly large number of such variables which conventional wisdom, current educational practice, and the endeavors of educational researchers have identified as being related to mathematics achievement, a limited number were selected for examination in the Mathematics Assessment. (See Chapter 1, Section 1.4)

A great deal more information concerning the possible relationships between certain personal background variables and achievement on the Mathematics Assessment test was collected than could possibly be reported in this volume. A more complete rendering of the data may be found in the Technical Report, which is obtainable from the Learning Assessment Branch. Researchers or others who wish to have access to the original data in order to seek answers to their own questions on issues relevant to the Mathematics Assessment should also direct their requests to the Learning Assessment Branch.

In the sections which follow, all of the results reported are based upon correlational trends. No attempt has been made to imply that cause and effect relationships exist since the Mathematics Assessment was not designed to identify such relationships. It remains for studies designed as follow-ups to the present one to seek to identify such relationships. Thus, while the assessment results show some fairly strong relationships between use of a hand-held calculator and student achievement, these relationships do not imply that a student's achievement in mathematics is determined by or is even influenced by the use of such a device. All that can be said on the basis of the assessment data is that there seems to be a relationship between the two variables. Indeed, it may be the case that both of the variables are the effect of a common, and as yet unidentified, cause.

For each of the reporting categories discussed in succeeding sections, reference is made to the various domains, objectives, and items evaluated in the Mathematics Assessment. For ease of reference, a labelling system has been adopted and will be used throughout the remainder of the chapter. Each objective has been assigned a code number consisting of two digits separated by a period. For example, Objective 2.3 refers to Domain 2 (Comprehension), Objective 3 (Understanding of Measurement Concepts). In Table 3-19 which follows, the right hand column indicates the section. of Chapter 3 where the grade/year 4 population results for the appropriate objective were discussed.

Table 3-19
Grade/Year 4: Code Numbers Used for Objectives

Code No.	Objective	Location of Population Results
1.1	Number Facts	Section 3.3.1
1.2	Addition of Whole Numbers	Section 3.3.2
1.3	Subtraction of Whole Numbers	Section 3.3.3
1.4	Knowledge of Notation and Terminology	Section 3.3.4
2.1	Understanding of Place Value Concepts	Section 3.4.1
2.2	Understanding of Number Properties	Section 3.4.2
2.3	Understanding of Measurement Concepts	Section 3.4.3
2.4	Understanding of Fraction Concepts	Section 3.4.4
3.1	Social Applications	Section 3.5.1
3.2	Mathematical Applications	Section 3.5.2

3.6.1 Age

On the background information section of the Mathematics Assessment instrument, students were asked to provide the month, day, and year of their birth. The major reason for collecting this data was to see what, if any, effect a student's age had on his or her achievement in mathematics. Previous research has shown that especially in the lower grades, there appears to be a relationship between age and mathematics achievement.

The data on students' performance by age are presented in two ways. First, in Figure 3-9, a comparison among the four age-groups of children at the Grade/Year 4 level who took the Mathematics Assessment test is portrayed graphically. Secondly, in Figure 3-10, a comparison among three groups of students all of whom attained the age of nine years during 1976 is made on the basis of the portion of the year 1967 in which they were born.

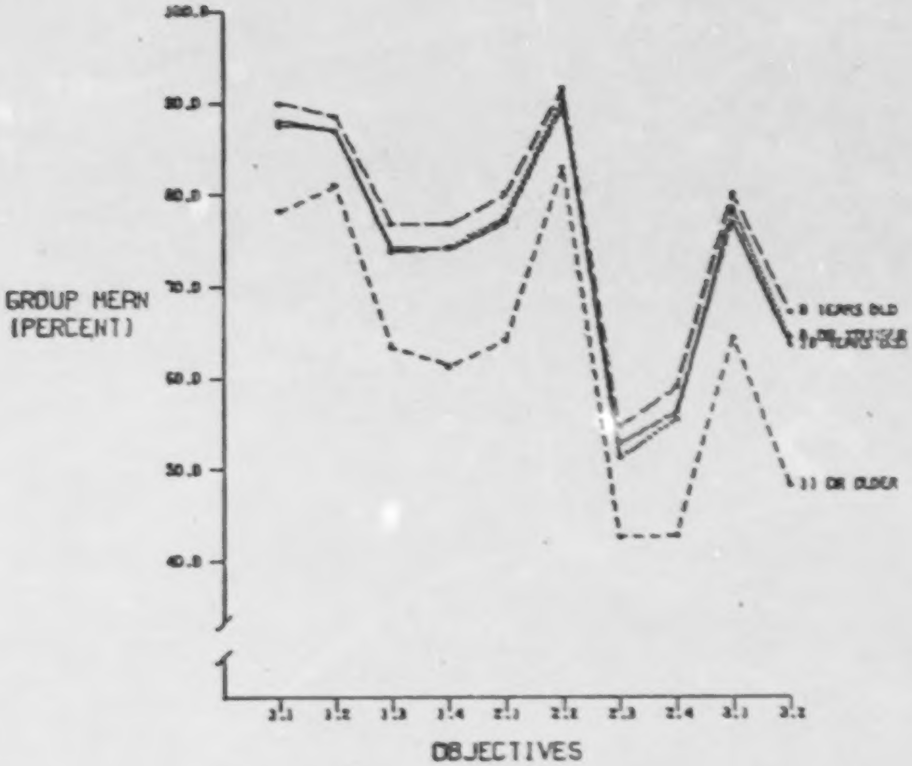


Figure 3-9: Grade/Year 4: Results by Age

The nine year olds' performance is superior to that of the other three groups on each objective. It is not unexpected for the eleven or older group to be so much lower than the others since the students in this group are students whose academic progress has been retarded for one reason or another. This group which numbered 1,686, or about five percent of the total, would likely include students from special classes and other special programs as well as children whose language background was other than English.

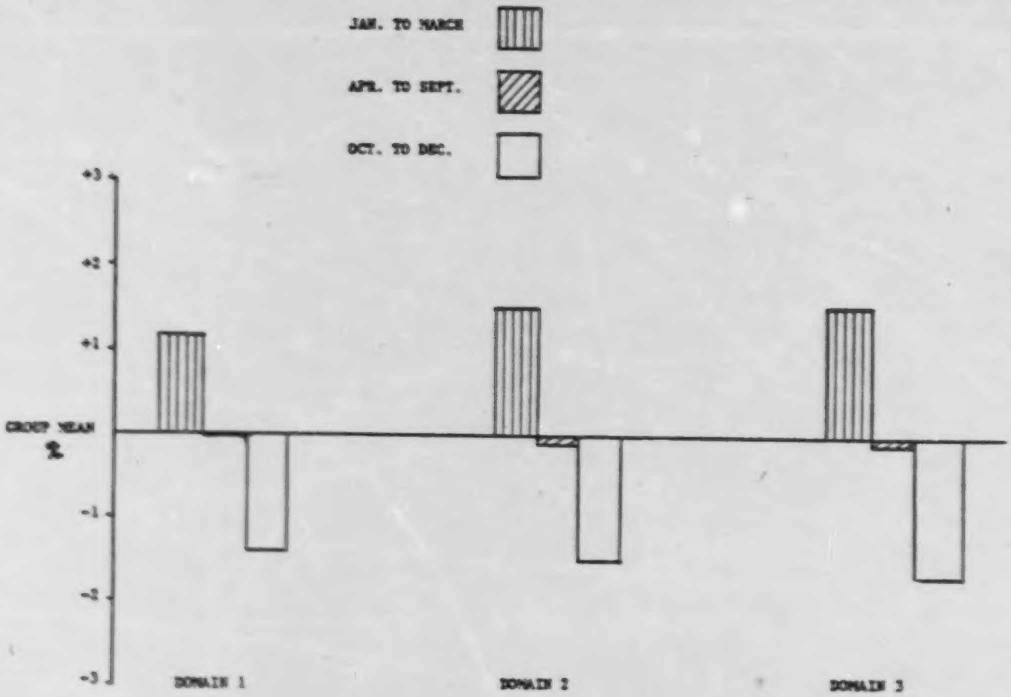


Figure 3-10: Grade/Year 4: Results by Age

In Figure 3-10 a bar graph is used to compare the performances of three groups of children in Grade/Year 4 who were born in 1967. Instead of making comparisons on each objective, only domain results have been shown.

The results shown in Figure 3-10 lend support to the thesis that children born earlier in a given year have an academic advantage over those born later in the same year. All of these children are nine years old and all are enrolled in grade/year 4. That is, they have been in school for the same length of time. In spite of that, children born between January and March 1967 had the highest mean percent correct on each of the ten objectives in the three domains. The greatest margins in favor of this group were obtained on the following objectives:

1) Knowledge of Notation and Terminology,
2) Understanding of Measurement Concepts,
3) Understanding of Fraction Concepts,
and 4) Mathematical Applications.

3.6.2 Sex Differences

Girls at the Grade/Year 4 level obtained a higher mean percent correct on five of the ten objectives assessed than did boys. Three of these objectives were from Domain 1: Number Facts, Addition of Whole Numbers, and Subtraction of Whole Numbers. The other two were from Domain 2: Comprehension of Number Properties and Comprehension of Fraction Concepts. The boys obtained higher scores on the other five objectives, one from Domain 1, two from Domain 2, and both problem-solving objectives which made up Domain 3. The results portrayed in Figure 3-11 show that all of the differences were slight.

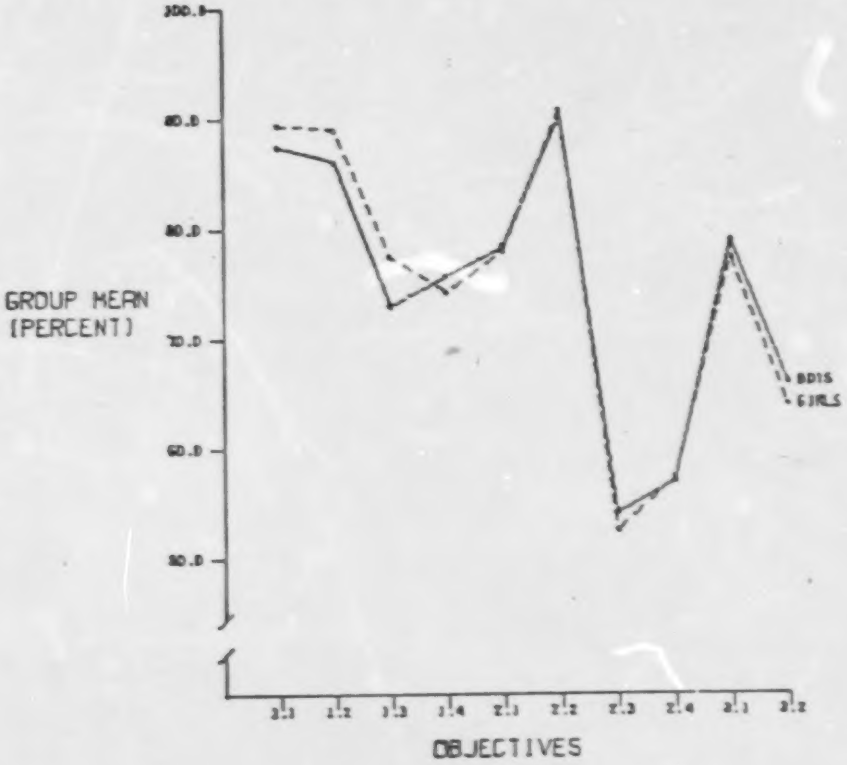


Figure 3-11: Grade/Year 4 Results by Sex

3.6.3 Number of Schools Attended

The results displayed in Figure 3-12 show not only that students who have attended only one elementary school achieve higher results than others but also that the results continue to decrease with each increase in the number of schools attended. This pattern holds true for all ten objectives.

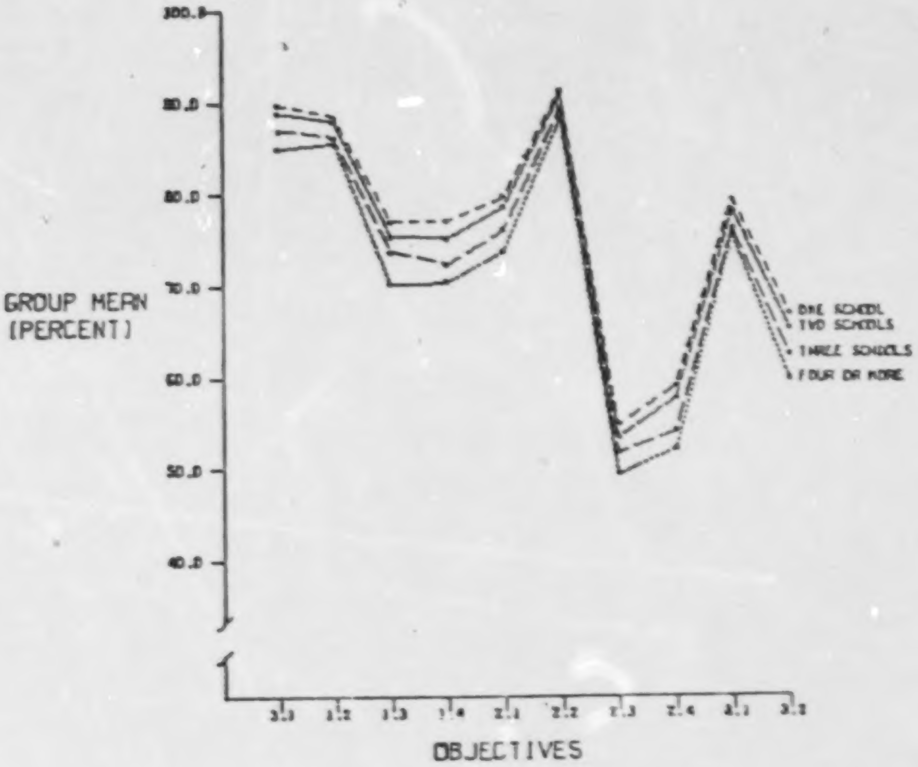


Figure 3-12: Grade/Year 4 Results by Number of Schools Attended

Further investigation is needed to discover the precise nature of the relationship between number of schools attended and achievement in mathematics. These results seem to indicate a fairly strong negative relationship between the two variables, but they cannot identify the exact nature of that relationship.

3.6.4 Use of Hand-Held Calculators

Students in Grade/Year 4 were asked four questions about their use of hand-held calculators. Have you ever used a hand-held calculator? Do you ever use a hand-held calculator at home? Do you sometimes use a hand-held calculator at home? Do you sometimes use a hand-held calculator to do your homework? Do you sometimes use a hand-held claculator in school? Their performances on the test as functions of their responses to these questions are summarized in Figures 3-13 through 3-16.

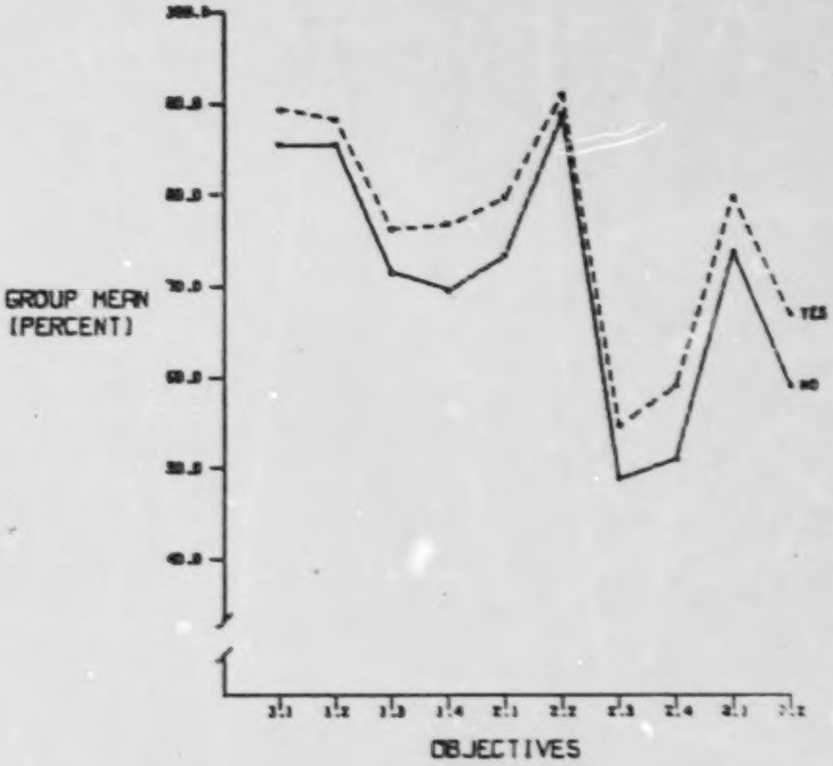


Figure 3-13: Grade/Year 4 Results by Whether or Not Pupils Had Had Any Experience with Calculators

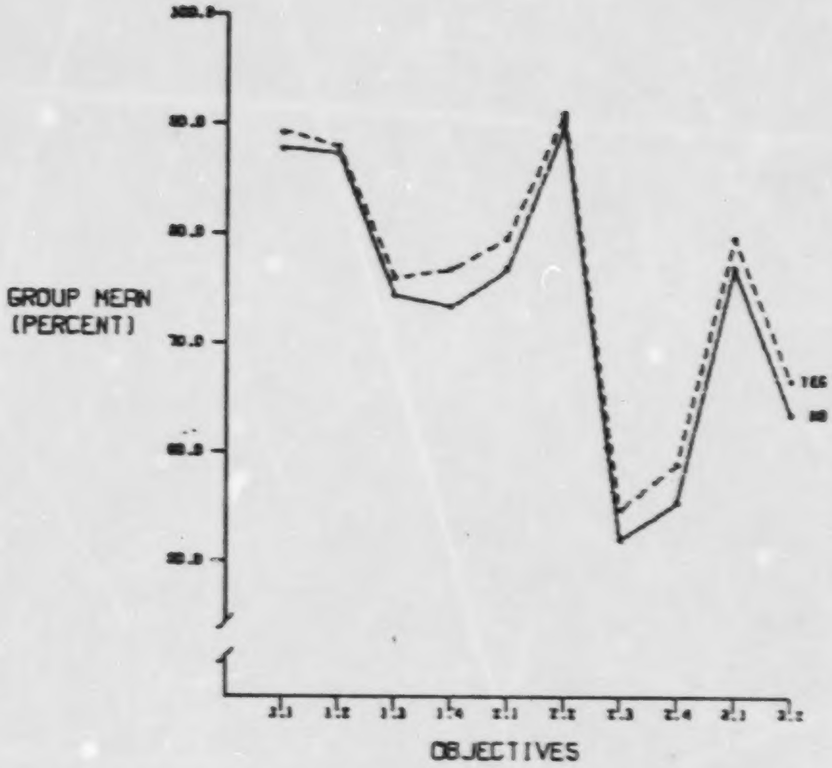


Figure 3-14: Grade/Year 4 Results by Whether or Not Pupils Used Calculators at Home

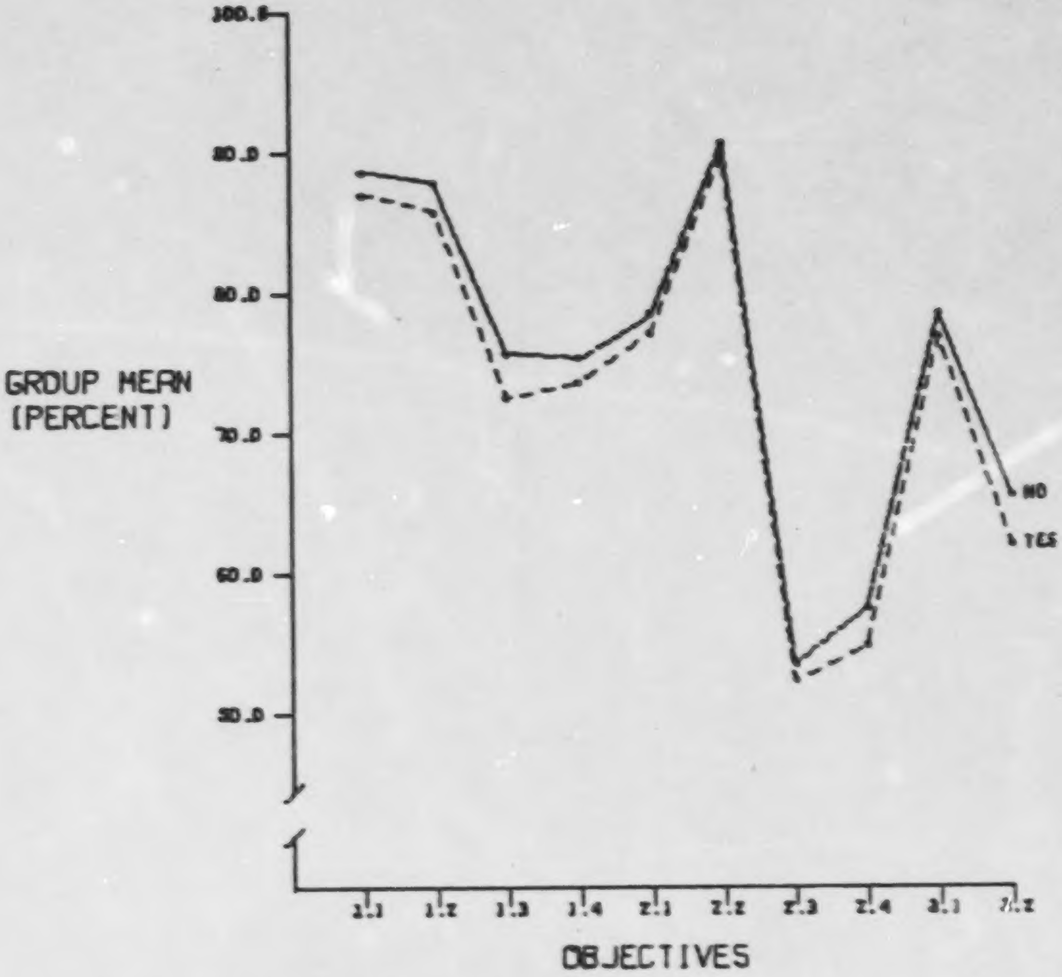


Figure 3-15: Grade/Year 4 Results by Whether or Not Pupils Used Calculators for Homework

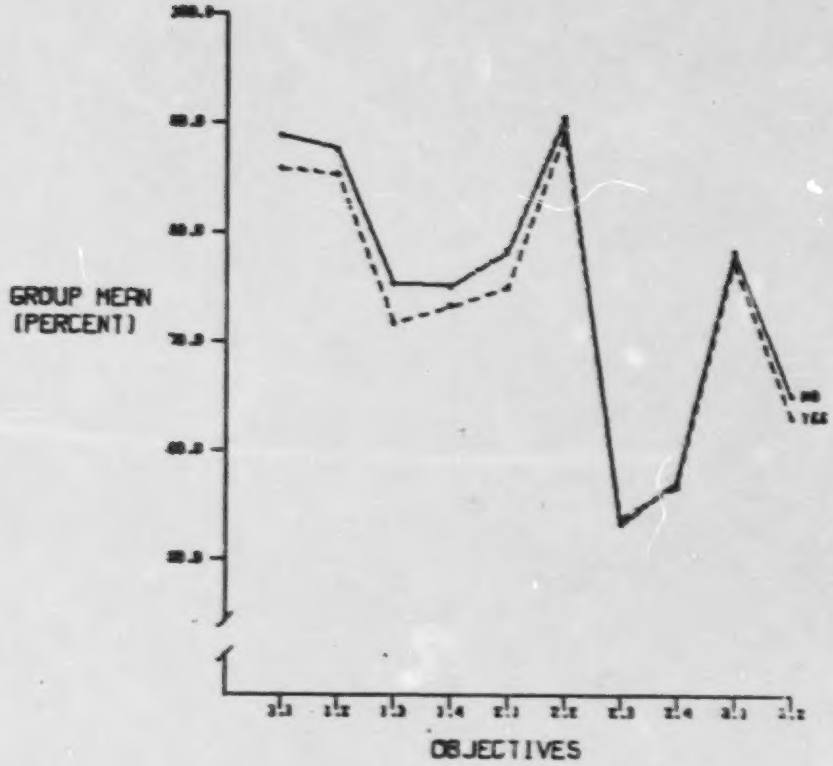


Figure 3-16: Grade/Year 4 Results by Whether or Not Pupils Used Calculators in School

3.6.5 Number of Hours of Television Watched

Language B.C. results showed an increase in performance in reading with an increase in the amount of television watched up to two hours per day, and then a gradual decrease to the four or more hours of television watching per day category. The comparable results for mathematics are shown in Figure 3-17.

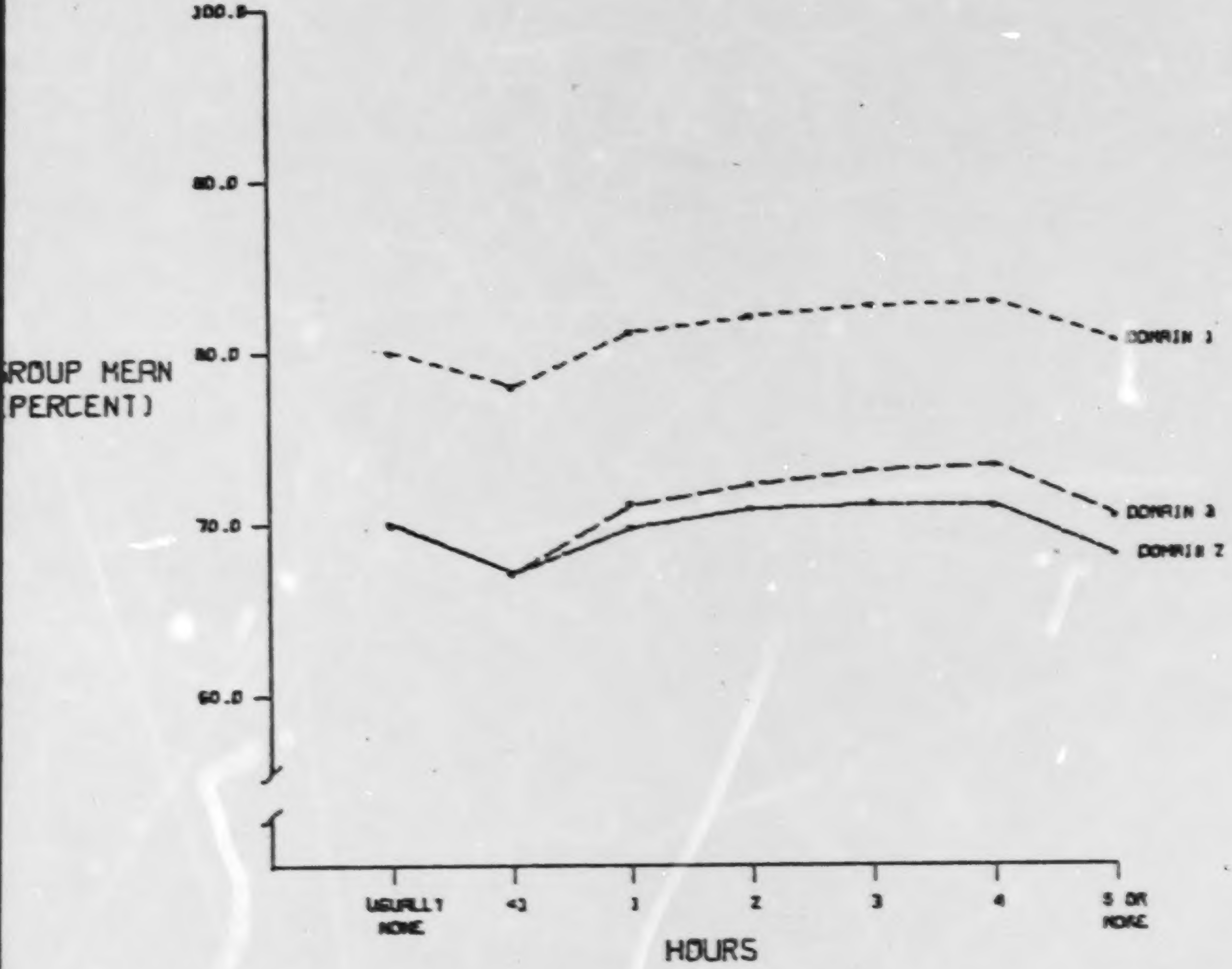


Figure 3-17 Grade/Year 4 Results by Daily Television Watching

In Figure 3-17 the domain results for the Grade/Year 4 students are divided into seven categories on the basis of their responses to the television watching item on the background information section of the mathematics test.

Students who watch about four hours of television per day obtained the best results in each domain, followed closely by those who watch about three hours per day. Curiously, the worst results were obtained by students who said they watch no television, five hours or more, or less than one hour per day. Whereas Language B.C. noted a general increase up to two hours per day, here there is a consistent increase in performance up to four hours per day, almost as much time as children spend in school.

3.6.6 Language Group

Grade/Year 4 students were asked three questions concerning the languages they spoke and national origin: These items are reproduced below.

4. Were you born in Canada?

Yes .... ☐ 1
No .... ☐ 2

6. Did you usually speak a language other than English before you started Grade 1?

Yes .... ☐ 1
No .... ☐ 2

7. Is English the language usually spoken in your home?

Yes .... ☐ 1
No .... ☐ 2

On the basis of their replies to these four items, students were divided into five groups as follows:

a. Non-Canadian, Non-English: All Grade/Year 4 students who responded "no" to item 4, "yes" to item 6, and "no" to item 7.

b. Canadian, Non-English: All Grade/Year 4 students who responded "yes" to item 4, "yes" to item 6, and "no" to item 7.

c. First Generation Canadians: All Grade/Year 4 students who responded "yes" to item 4, "no" to item 6, and "no" to item 7.

d. Non-Canadian, English: All Grade/Year 4 students who responded "no" to item 4, "no" to item 6, and "yes" to item 7.

e. Canadian, English: All Grade/Year 4 students who responded "yes" to item 4, "no" to item 6, and "yes" to item 7.

The performace of each of the five groups was computed for each domain and they are summarized in Figure 3-18.

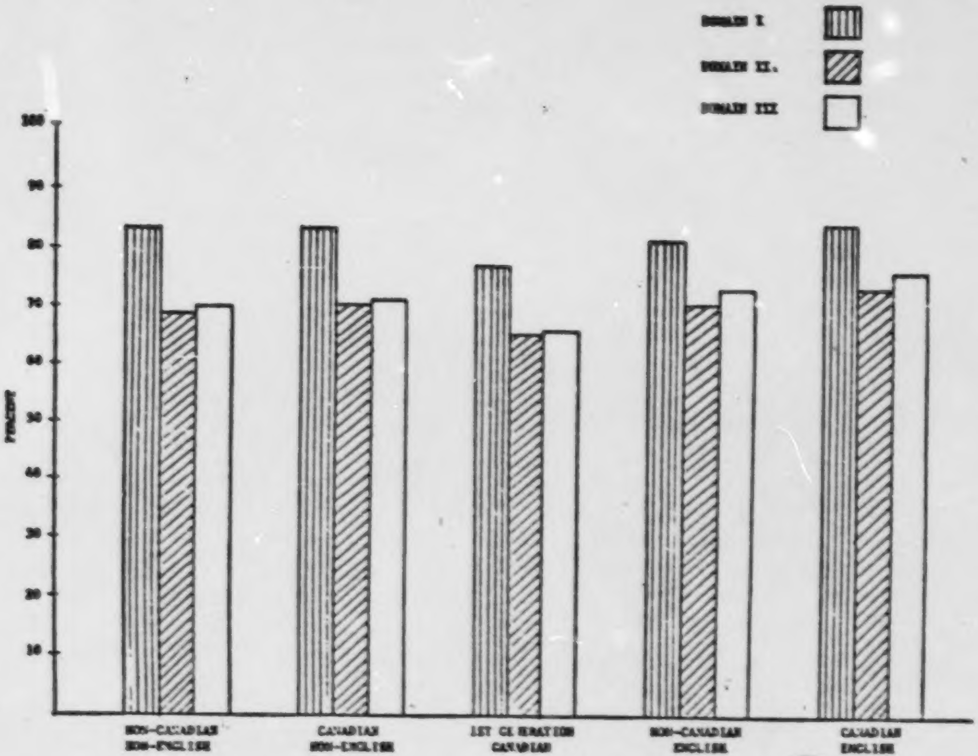


Figure 3-18: Grade/Year 4 Results by Language Group

The Canadian, English-speaking group achieved the highest results overall. The results for the non-English -speaking groups and for the other two English-speaking groups were similar to each other. The First Generation Canadian group's performance lagged behind. In Domain 3 where more reading and knowledge of notation and terminology were required, the difference between the English- and non-English-speaking groups was greatest.

The results for Domain 1 show that the non-English-speaking groups outperformed the English-speaking groups. Unlike Language B.C., the overall performace of the two non-English-speaking groups on the Mathematics Assessment was about the same as that of the Non-Canadian English-speaking group.

3.7 Summary and Recommendations

The Grade/Year 4 test contained sixty-nine items designed to assess students' mastery of ten objectives grouped into three domains. In addition to these mathematics items, the test contained thirteen background information items which students were asked to complete before taking the test.

Items 1 - 39 on the Grade/Year 4 test were open-ended. Items 40 - 69 were multiple-choice exercises. Students responded to the test items in the test booklet itself by either writing the answer for open-ended exercises or marking their choice of answer with an "X" for the multiple-choice items. The information from the booklets was then keypunched into machine-readable format.

One and one-half hours were allotted for the test: thirty minutes for instructions, distribution and collection of the test booklets and completion of the background information items, and sixty minutes for completion of the test itself. The background information items were administered first. Teachers administering the test were asked to read each of these items aloud to their students and to assist them in completing the items correctly.

The test itself was divided into three parts. Part 1 was timed and consisted of twenty-four basic fact items, six for each of the operations of addition, subtraction, multiplication, and division. Students were given four minutes to complete this portion of the test. Parts 2 and 3 were not speed tests; students were given one hour to do the items on this portion of the test. Part 2 consisted of fifteen open-ended items dealing with computational skills. Part 3 contained thirty multiple-choice exercises.

The Grade/Year 4 Mathematics Assessment was designed for all students enrolled in their fourth year of schooling. According to statistics released by the Ministry of Education, 36 540 children were enrolled in Grade 4 as of 28 February, 1977. The Mathematics Assessment test was written by 35,277 students or 96.5% of that total. This falls well within the normal range of attendance at this grade level. Approximately 1000 more boys than girls took the test.

3.7.1 Background Information

The assessment instrument was administered during the month of March 1977. At that time, a student should have been either nine or ten years old if he was age six at the time of his first enrollment in Grade 1. About ninety percent of the Grade/Year 4 students were within the normal age range expected.

The results on the item concerning the number of schools attended attest to the high degree of mobility that exists among the families of British Columbia since the number of schools attended by a child is highly correlated with the number of residences in which the child has lived. Less than half the population has been in only one school since beginning Grade/Year one.

Other background information showed that seventy-five percent of the students are of Canadian origin and fifteen percent have a language other than English as a first language. Over two-thirds of the students watch three hours or more television per day, and almost one-third of the Grade/Year 4 students appear to spend as much time watching television on a weekday as they spend at school.

The data gathered on hand-held calculators showed that over three-fourths of the students have used a hand-held calculator, but only three percent have used a hand-held calculator in school.

3.7.2 Test Results

The sixty-nine items on the Grade/Year 4 test were divided among three domains: Computation and Knowledge (Domain 1, 40 items), Comprehension (Domain 2, 17 items), and Applications (Domain 3, 12 items). Each domain was subdivided into a number of objectives and the items were generated to measure mastery of the objectives.

The Grade/Year 4 students' performance on the items of Domain 1 was very satisfactory with only one weakness noted. Good performances on the items outnumbered the poor performances by a two to one margin. The noted weakness was on a subtraction exercise that involved both a zero in the minuend and regrouping. That item was one of the items for Objective 1.3, Subtraction of Whole Numbers. The poorest performace in Domain 1 was on Objective 1.3. The best performace in Domain One was on the six basic facts for addition on which the average percent correct was 96.6%.

Other areas where the Grade/Year 4 performance was rated as very satisfactory in Domain 1 were subtraction and multiplication basic facts, addition of whole numbers, and reading time and temperature.

The Grade/Year 4 students' performace on the items of Domain 2 was mixed, with as many weaknesses as strengths being noted. The pattern of performance, however, was very clear. Performance on both items of Objective 2.4, Understanding of Fraction Concepts was poor; and also on three of the five items of Objective 2.3, Understanding of Measurement Concepts. In Objective 2.3, less than one-third of the students could correctly respond with a likely temperature for a sunny summer day. In Objective 2.4, barely half of the students could identify the box that was one-fifth (1/5) shaded.

On the positive side, the students performed extremely well on Objective 2.2, Understanding of Number properties with ninety-five percent of the students correctly applying the additive and multiplicative identities and ninety percent correctly applying the multiplicative property of zero.

Grade/Year 4 students performed well on both objectives of Domain 3 with the performance on two items being rated as strengths and no performance rated as a weakness. Only one item was rated below satisfactory and four items were rated above satisfactory. The poorest performance was on an item involving subtraction with time. The performances rated as very satisfactory were on items concerning money and reading a graph. The performance on the other item involving reading a graph was rated as a strength, as was the performance on the word problem involving the addition of whole numbers.

3.7.3 Reporting Categories

Mathematics achievement is the end result of the coalescing of a great number of student-based factors, both extrinsic and intrinsic. Attributes inherent in the student, programmatic and curricular variables, as well as the effect of environmental variables such as teacher differences all contirubte in varying and largely unknown degree to a given student's overall performance. Of the fairly large number of such variables which the conventional wisdom, current educational practice, and the endeavors of educational researchers have identified as being related to mathematics achievement, the ones that were selected for scrutiny in the Grade/Year 4 Mathematics Assessment were age, sex, number of schools attended, use of hand-held calculators, television watching, and language.

Age Differences -- The nine year olds had the highest performance and the eleven year olds had the lowest performance on each of the ten objectives. Considering just those students who turned nine years old during 1976, the results supported previous research which says that older children have an academic advantage over their younger counterparts at the same level.

Sex Differences -- Each group performed better than the other on five of the ten objectives, but of the five objectives on which the girls obtained the higher performance three were in Domain 1.

Number of Schools Attended -- Those Grade/Year 4 students who had attended only one school performed better than all the other groups on every objective. The pattern exhibited was that the fewer schools attended, the higher the performance. The pattern held for all ten objectives.

Use of Hand-Held Calculators -- Two distinctly different patterns were noted in the data collected on the four questions concerning the use of hand-held calculators. Students who had used hand-held calculators achieved better results on each of the ten objectives than those students who had never used hand-held calculators. The same pattern held on every objective for those students responding that they used a calculator at home compared to those who had never used a hand-held calculator at home. The performace pattern was reversed for those students who had used a hand-held calculator for homework and for those students who had used a hand-held calculator in school.

Television Watching -- The general pattern was that the more hours of television watched up to four hours per day, the higher the performance. However, the differences were small.

Language -- The Grade/Year 4 data were grouped according to whether the students had been born in Canada, whether they usually spoke a language other than English before starting Grade 1, and whether English was the language usually spoken in the home. The average performance of the Canadian, English-speaking group was best of the five groups. The two non-English-speaking groups performed equally as well as the non-Canadian English speaking groups and this was a rather surprising result. The first generation Canadian group's performance lagged behind.

3.7.4 Recommendations

Based on the data presented in this chapter, the following recommendations were made.

Recommendation 3-1: *Teachers of mathematics should have access to and make liberal use of appropriate manipulative devices for the teaching of place value concepts and of operations on numbers. This recommendation is equally important at both the primary and the intermediate levels.*

Recommendation 3-2: *Persons involved in the pre-service or in-service education of teachers are urged to emphasize the importance of having students make use of manipulative devices as models for mathematical concepts and skills at all times, but particularly when such concepts and skills are being introduced for the first time.*

Recommendation 3-3: *Educators should attempt to identify a list of mathematical terms which students should learn as well as a teaching sequence for developing this vocabulary. The list and sequence should take into account the developmental nature of the acquisition of meaningful mathematical vocabulary.*

Recommendation 3-4: *The importance of place value skills and concepts, including estimation, cannot be over-emphasized. Teachers and those involved in teacher education should stress the necessity of developing understanding of place value concepts by building upon a foundation of concrete learning experiences.*

Recommendation 3-5: *The Ministry of Education local school districts, and professional associations should cooperate in ensuring that materials for teaching the metric system of measurement are available in all schools.*

Recommendation 3-6: *Follow-up workshops and conferences, designed to emphasize the best materials, methods, and techniques to be used in teaching measurement should be provided. Such professional development workshops should emphasize the importance of students' obtaining "hands-on" experience in measuring in order to facilitate the development of their ability to "THINK METRIC".*

Recommendation 3-7: *Educators, curriculum developers, and educational researchers should address the problem of the optimum time for introducing fraction concepts in the mathematics classroom bearing in mind both the children's developmental level and the sophistication of the ideas involved in these concepts. When introductory fraction concepts are being developed, both models, part of a whole and part of a set, should be emphasized.*

Recommendation 3-8: *Teachers of mathematics should emphasize classroom, school, and local situations for developing "real" problem-solving experiences which will be relevant to their students.*

Chapter 4

Grade 8: Results, Interpretation, and Recommendations

The results of the assessment for the Grade 8 level are presented in this chapter, organized by domain and objective. Specific items are presented when an illustration is needed for the discussion of an objective. Due to space limitations, it has not been possible to present and discuss each item. More detailed information concerning each item is presented in Report Number 3: Technical Report.

4.1 Description of the Test

The Grade 8 test has sixty content items measuring acquisition of twelve objectives in three domains. In addition to the content items, the test contained ten items dealing with student background information. Both the content and background items were presented in the multiple choice format. Every content item had five foils or distractors. Four of the distractors were possible answers while the fifth distractor was "I don't know". Students responded to the test items by marking their responses on a mark-sense card which had been specially designed for the Grade 8 Mathematics Assessment.

Pilot testing of the Grade 8 test was carried out in several schools across the province (see Appendix B for a list of participating schools). The main purposes of the pilot testing were item verification and timing since the instruments of the Mathematics Assessment were not designed to be speed tests. The results of the pilot testing showed that a majority of the students had completed the test in forty minutes and virtually every student was finished in fifty-five minutes. A total of ninety minutes was allowed for the entire assessment: thirty minutes for the distribution of tests, instructions, completion of background items, and collecting of tests; and sixty minutes for the students to respond to the content items.

4.2 Description of the Population

The Grade 8 Mathematics Assessment was designed for all students enrolled in Grade 8. According to statistics released by the Ministry of Education, 46 888 students were enrolled at that level as of 28 February 1977. Usable mark-sense cards were obtained from 42 250, or 90.1% of the total. The best information available from the Ministry of Education is that 8.1% absenteeism is the rate that may be expected on any given day at the junior secondary level. This figure is considered by many to be a conservative estimate of the actual rate.

4.2.1 Distribution by Age

The assessment test was administered during the month of March 1977. At that time a student who was six years old at the time of his enrollment in grade one should have been either thirteen or fourteen years old. The data shown in Table 4-1 show that over 90% of the Grade 8 students do fall within the normal range of ages expected.

Table 4-1

Grade 8: Age of Respondents

Age	Frequency	Percent
10 or younger	36	0.0
11	39	0.0
12	682	1.6
13	24 075	56.9
14	14 237	33.6
15	2 344	5.5
16	376	0.8
17	64	0.1
No response	397	0.9

4.2.2 Distribution by Sex

As mentioned in Chapter 1, differences in achievement levels between boys and girls have been of interest to educators for some time. The Grade 8 level has been mentioned in the research literature as the approximate point where boys begin to achieve higher scores than girls with respect to mathematics achievement at the higher cognitive behaviour levels.

Table 4-2

Grade 8: Sex of Respondents

Sex	Frequency	Percent
Male	21 470	50.8
Female	20 162	47.7
No response	537	1.2
Multiple response	81	0.1

Approximately 1300 more males than females took part in the assessment. Overall, as is shown in Table 4-2, 50.8% of the respondents were boys while 47.7% were girls. This slight preponderance of boys also existed at the Grade/Year 4 level, but was reversed at the Grade 12 level.

4.2.3 Number of Schools Attended

The results of this item attest to the high degree of mobility that exists among the families of British Columbia since the number of schools attended is highly correlated with the number of residences in which the child has lived. Almost one out of every four (23%) Grade 8 students in the province has already attended five or more schools. Less than a third (32.7%) of the Grade 8 students have attended only two schools, presumably one elementary school and one secondary school. Such a low percentage cannot be supported by saying that during elementary school many student attended two schools, a primary school or annex and an intermediate school, since such schools represent only 2.5% of the elementary schools in the province.

Table 4-3
Grade 8: Number of Schools Attended

Number of Schools Attended	Frequency	Percent
1	1 367	3.2
2	12 479	29.5
3	11 124	26.3
4	6 970	16.4
5	4 055	9.5
6	2 236	5.2
7	1 291	3.0
8 - 9	1 217	2.8
10 or more	1 096	2.5
No response	415	0.9

4.2.4 Hand-Held Calculators

The hand-held calculator is the latest in a series of teaching and learning aids which seem to hold promise for the improvement of students' achievement in and understanding of mathematics. A good deal of research interest in the field of Mathematics Education is currently focussed upon an examination of the effect of the use of hand-held calculators in the mathematics classroom.

As part of the Mathematics Assessment, students at all three levels involved were asked several questions concerning their use of hand-held calculators. Their responses to these questions are summarized in Table 4-4.

Table 4-4

Grade 8: Use of Hand-Held Calculators

Category of Use	Grade 4	Grade 8	Grade 12
Have never used calculator in school	23.3	Question not asked	
Have used calculator at home	49.9	35.1	50.6
Have used calculator for homework	12.8	28.9	55.7
Have used calculator in school	3.0	10.1	51.2

The data shown in Table 4-4 reveal three very interesting results. First, as students go through the grades in British Columbia schools more of them use hand-held calculators in school and for homework. Secondly, a smaller percent of Grade 8 students use a hand-held calculator at home than either of the other two levels tested. Thirdly, the percent of Grade 12 students using a hand-held calculator in school is over five times greater than in Grade 8.

The fact that only 3% of children in Grade/Year 4 and only 10% of the students in Grade 8 have used a calculator in school may be indicative of the fact that educators are not convinced of the advisability of using calculators with students at these levels.

4.2.5. School Organization

Whether a secondary school is semestered or not is a major factor in determining the organization of the mathematics teaching. As the data in Table 4-5 show, however, fewer than one third of the Grade 8 students have taken a semestered version of Mathematics 8.

Table 4-5

Grade 8: Semestering of Mathematics Courses

	Frequency	Percent
Semestered	12 865	30.4
Non-Semestered	28 799	68.1
No response	470	1.1
Multiple response	116	0.2

4.2.6 Mathematics Background

Not every student enrolled in Grade 8 takes Math 8. Some students follow accelerated programs while others may still be taking Grade 7 mathematics. The results displayed in Table 4-6 show that the overwhelming majority of students at this level, 87.5%, are taking Math 8. The 6.7% who are not taking mathematics probably are enrolled in semestered schools and completed their mathematics course in the first semester.

Table 4-6
Grade 8: Mathematics Background

Course	Highest Course Completed		Current Course	
	Frequency	Percent	Frequency	Percent
Mathematics 7	34 050	80.5	733	1.7
Mathematics 8	6 077	14.3	37 000	87.5
Mathematics 9	199	0.4	480	1.1
Other	880	2.0	625	1.4
None	0	0.0	2 877	6.7
No response	665	1.5	362	0.8
Multiple response	379	0.8	184	0.4

4.2.7 Mathematics Homework

The data in Table 4-7 shows that one out of every seven Grade 8 students spends no time at all on mathematics assignments outside of regular mathematics class. Fewer than one out of every three Grade 8 students spends more than thirty minutes on mathematics homework.

Table 4-7
Grade 8: Mathematics Homework

Amount of Time Spent on Mathematics Homework	Frequency	Percent
None at all	6 238	14.7
Less than 30 minutes per day	23 346	55.2
30 - 60 minutes per day	10 802	25.5
More than 60 minutes per day	1 237	2.9
No response	525	1.2
Multiple response	102	0.2

4.3 Test Results: Computation and Knowledge Domain

As discussed in Chapter 2, the sixty items on the Grade 8 tests were divided among three domains, and each domain was sub-divided into a number of objectives. In this section, the results from the Computation and Knowledge domain are discussed, objective by objective.

The Computation and Knowledge domain encompassed six objectives, mastery of which was measured by thirty-two items. For each objective of each domain, the following information is provided:

1) the number of the item or items from the test;
2) the percent of students who obtained the correct answer to each item; and
3) the judgment of the Interpretation Panel concerning the acceptability of the result.

4.3.1 Computation with Whole Numbers

By the end of Grade 7 students are expected to be able to perform the four basic operations of addition, subtraction, multiplication, and division on several different sets of numbers. This expectation is reflected by the objectives in this domain. The most basic computation is with whole numbers. The results of the five items used to measure acquisition of this objective are presented in Table 4-8.

Table 4-8
Grade 8 Results (N = 42 250)
Objective: Computation with Whole Numbers (mean = 83.8%)

Item No.	Operation	Percent Correct	Panel Judgment
4	Addition	93	Very Satisfactory
8	Division	70	Marginally Satisfactory
16	Subtraction	89	Very Satisfactory
32	Addition	88	Very Satisfactory
49	Multiplication	79	Satisfactory

The Interpretation Panel expressed the opinion that the results for this objective were very satisfactory with the exception of division. The mean of 83.8% for this objective is impressive. Combining a high overall mean for the objective with the fact that division is the most difficult of the four basic operations and that it is the last of the four operations to be developed in the elementary curriculum leads to the conclusion that the Grade 8 level students' performance on computation with whole numbers was encouraging.

4.3.2 Computation with Fractions

The test contained four items to assess the students' ability to perform the four basic operations using rational numbers in fraction form. The results for the four items are found in Table 4-9.

Table 4-9
Grade 8 Results (N = 42 250)
Objective: Computation with Fractions (mean = 68.2%)

Item No.	Operation	Percent Correct	Panel Judgment
2	Addition	66	Marginally Satisfactory
6	Subtraction	63	Marginally Satisfactory
11	Division	62	Satisfactory
29	Multiplication	82	Very Satisfactory

The Interpretation Panel's comments with respect to the results presented in Table 4-9 were that the students' performance was generally satisfactory, with no particular weakness evident in any of the operations. The Panel recognized that operations with fractions are difficult and this resulted in lower performance.

The multiplication algorithm for rational numbers in fraction form requires the fewest steps of the four operations and the performance reflects this fact. The division algorithm, however, requires fewer steps than either the addition or subtraction algorithms for rational numbers in fraction form with unlike denominators and the performance does not reflect this fact. Instead of applying the "invert and multiply" process, 15% of the students simply multiplied.

Items 2 and 6 were exercises involving unlike denominators. For Item 2, an addition problem, 19% of the students simply added the numerators and added the denominators. For Item 6, a subtraction problem, 22% of the students simply subtracted the numerators and subtracted the denominators. These errors on Items 2 and 6 represent 58% and 69%, respectively, of the students making errors. Students making these types of errors do not show an understanding of the processes of adding and subtracting rational numbers in fraction form.

4.3.3 Computation with Decimals

As discussed in Chapter 2, the emphasis in the Computation and Knowledge Domain for Grade 8 was on computation with different sets of numbers. The results for Computation with Decimals are presented in Table 4-10.

Table 4-10
Grade 8 Results (N = 42 250)
Objective: Computation with Decimals (mean = 67.6%)

Item No.	Operation	Percent Correct	Interpretation
1	Subtraction	79	Satisfactory
5	Multiplication	63	Marginally Satisfactory
15	Addition	72	Satisfactory
17	Subtraction	66	Satisfactory
28	Division	58	Marginally Satisfactory

The Interpretation Panel felt that the students' performance was generally satisfactory. The Panel continued by emphasizing that in view of the implementation of the metric system of measurement, decimal computation is becoming more important.

One factor that may have affected the performance level was format of the items. The addition, subtraction, and multiplication problems were presented in horizontal form which is considered more difficult than the vertical form (e.g., Item 1 was presented in the form on the left in Figure 4-1 as opposed to the form on the right).

Horizontal	Vertical
62.1 - 23.8 =	62.1 - 23.8

Figure 4-1: Horizontal and Vertical Format

A factor involved in the difference in performance between Item 1 and Item 17, both subtraction problems, is that Item 17 was a "ragged alignment" problem. In such an exercise, one of the two numbers is presented with more digits to the right of the decimal point than the other. Before students can do a ragged alignment exercise, they must correct the alignment by either physically or mentally placing zeros in the appropriate places.

Recommendation 4-1: Due to the increasing importance of the decimal form of rational numbers, all teachers of mathematics should take special care to lay the foundation for understanding of the expansion of the numeration system to the decimal form for rational numbers. Understanding of the decimal form of rational numbers should then be used to improve performance with the four basic operations using the decimal form of rational numbers.

Recommendation 4-2: In future materials produced by authors and curriculum developers, the decimal form of rational numbers should precede the fraction form. The overall curriculum should place much greater emphasis on the decimal form.

4.3.4 Knowledge of Notation and Terminology

At every level students are expected to be familiar with certain commonly used mathematical terms as well as with the symbols used to represent various operations, relationships and quantities. Nine items on the Grade 8 test were designed to assess students' familiarity with such notation and terminology. Results for the nine items are presented in Table 4-11.

Table 4-11
Grade 8 Results (N = 42 250)
Objective: Knowledge of Notation and Terminology (mean = 70.8%)

Item No.	Topic	Percent Correct	Panel Judgment
3	Square root	51	Marginally Satisfactory
7	Factor	78	Very Satisfactory
9	Powers of 10	73	Satisfactory
20	Centimetres	69	Satisfactory
30	Exponents	72	Very Satisfactory
33	Whole Number	88	Very Satisfactory
34	G.C.F.	73	Very Satisfactory
44	Reciprocal	80	Very Satisfactory
45	Primes	53	Marginally Satisfactory

The Interpretation Panel commented that the students' performance on this objective was, with the exception of Items 3 and 45, very satisfactory. The Panel did not have great concern about the low performance on Item 3, since square root is well covered in Math 8. It should be noted however, that the "I don't know" response was selected by 13% of the students on Item 3, the third highest ranking for that response on the entire test.

For Item 9, students were asked to simplify 10^4. Many students learn a rule for simplifying ten to any whole number power. The simplified form of that rule is simply one followed by n zeroes, where n is the specified exponent (e.g., 10^4 is 10 000). Seventy-three percent successfully completed Item 9, but 12% picked 100 000 as the answer which is ten followed by four zeroes. Those 12% may have been very close to understanding the symbol but misused the rule.

For Item 34 (see Figure 4-2), 73% of the students successfully computed the Greatest Common Factor. Another 11% seemed to misunderstand the term which was being assessed by this item, but successfully computed the Least Common Multiple of 24 and 30, an equally difficult exercise.

34. The greatest common factor of 24 and 30 is:	Percent
A) 2	9
B) 6	73
C) 120	11
D) 60	3
E) I don't know	3
No Response	1

Figure 4-2: Grade 8 - Item 34

As with Item 34, the performance on Item 7, presented in Figure 4-3, was impressive.

7. Which number is NOT a factor of 22?	Percent
A) 0	78
B) 1	11
C) 2	3
D) 22	3
E) I don't know	4

Figure 4-3: Grade 8 - Item 7

To be successful on Item 7, the students either had to correctly factor 22, or be familiar with the fact that zero is not a factor of any non-zero number. Item 7 is also stated in the negative form, one of only two such items on the test.

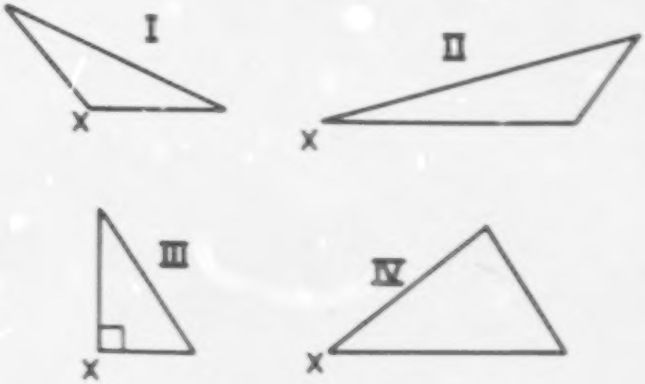
4.3.5 Knowledge of Geometric Facts

Four items were designed to assess the students' knowledge of geometric facts. The results of the four items are found in Table 4-12.

Table 4-12
Grade 8 Results (N = 42 250)
Objective: Knowledge of Geometric Facts (mean = 63.2%)

Item No.	Percent Correct	Panel Judgment
39	40	Marginally Satisfactory
40	63	Marginally Satisfactory
42	72	Satisfactory
55	78	Satisfactory

The Interpretation Panel was generally satisfied with students' performance on this objective. They felt the result on Item 39, see Figure 4-4, indicated that students' knowledge of types of angles was "hazy". Twenty-six percent of the respondents selected a right angle rather than an obtuse angle.



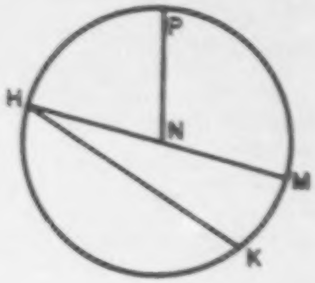
39. In which triangle is angle X an obtuse angle?

		Percent
A)	I	40
B)	II	12
C)	III	26
D)	IV	8
E)	I don't know	12
	No Response	1

Figure 4-4: Grade 8 - Item 39

Item 40, presented in Figure 4-5, is very similar in nature to Item 39. It was designed to require students not only to understand the term "diameter" but also to select a diameter from among three radii, a diameter, and a chord. The radius which was not a subset of the diameter was selected by 18% of the students.

40. If N is the centre, which segment is a diameter?



		Percent
A)	$\overline{HK}$	5
B)	$\overline{NP}$	18
C)	$\overline{HP}$	5
D)	$\overline{HM}$	63
E)	I don't know	8
	No response	1

Figure 4-5: Grade 8 - Item 40

Recommendation 4-3: Classroom teachers and those involved in the training of mathematics teachers should emphasize the importance of instruction in geometry in the elementary school mathematics curriculum, and show future teachers the place geometry holds in both mathematics and everyday life.

4.3.6 Equivalent Forms of Rational Numbers

The final objective in the Computation and Knowledge domain required students to begin with a rational number in one form and select the same rational number expressed in a different form. Five items were designed to measure the acquisition of the objective and the results for the five items are presented in Table 4-13.

Table 4-13
Grade 8 Results (N = 42 250)
Objective: Equivalent Forms of Rational Numbers (mean = 59%)

Item No.	Starting Form	Final Form	Percent Correct	Panel Judgment
13	Unit Fraction	Percent	55	Marginally Satisfactory
31	Unit Fraction	Decimal	38	Marginally Satisfactory
35	Percent	Decimal	47	Weakness
46	Proper Fraction	Lowest Terms	80	Very Satisfactory
51	Improper Fraction	Mixed Numberal	75	Satisfactory

Grade 8 students did not appear to have any particular difficulty in reducing fractions to lowest terms or in changing an improper fraction to its mixed numeral form. On the other hand, students experienced considerable difficulty in going from the fraction form to either the decimal form (Item 31) or the percent form (Item 13), and in going from the percent form to the decimal form (Item 35). After examining the performance on those three items, the Panel concluded that more emphasis should be given to relationships among rational numbers in fraction form, and percent form.

Both Items 13 and 31 are presented in Figures 4-6 and 4-7, so a comparison of the distractors selected may be made.

13. Written as a percent, $\frac{1}{5} =$

	Percent
A) 5%	19
B) 0.5%	19
C) 20%	55
D) 50%	2
E) I don't know	2
No response	1

Figure 4-6: Grade 8 - Item 13

31. Written as a decimal, $\frac{1}{8} =$

	Percent
A) 0.12	6
B) 0.8	41
C) 0.125	38
D) 0.18	8
E) I don't know	5
No response	1

Figure 4-7: Grade 8 - Item 31

On Item 13, all of the incorrect distractors use only the digits 5 and 0. It appears that 50% is associated with ½ closely enough not to cause confusion. However, 5% and 0.5% were each selected by 19% of the students. One could hypothesize that the selection was made because 5 is the denominator of 1/5. From the data one cannot tell how many students selected 20% simply because it used different digits than all the other distractors.

Adding the information from the results of Item 31 to the results of Item 13 strengthens the impression that students who selected an incorrect answer did so because the distractor used the same digit as the denominator of the fraction. The denominator of the fraction in Item 31 is 8 and distractor B is 0.8. It is the one distractor that uses only the digits 0 and 8, and it was chosen by 41% of the students.

Though the results may be due, in part, to the format of the distractors, the Panel was very disappointed in the performance (47%) of the students on Item 35.

Recommendation 4-4: Teachers of mathematics should emphasize the area of equivalent forms of rational numbers. Students need many experiences of starting with a rational number in fraction form, decimal form, or percent form and writing it in the other two forms.

4.4 Test Results: Comprehension Domain

The Comprehension Domain consisted of eighteen items measuring the acquisition of four objectives. The results for the items in the Comprehension Domain are presented in this section organized by objective.

4.4.1 Comprehension of Number Concepts

Six items were designed to assess the students' comprehension of number concepts. The results for the six items are presented in Table 4-14.

Table 4-14
Grade 8 Results (N = 42 250)
Objective: Comprehension of Number Concepts (mean = 53.5%)

Item No.	Percent Correct	Panel Judgment
10	90	Strength
12	42	Marginally Satisfactory
14	69	Satisfactory
18	32	Weakness
47	29	Weakness
50	59	Satisfactory

Item 12, see Figure 4-8, required the students to simplify 0/6. Students at all levels tend to have difficulty with properties of zero. The Interpretation Panel felt that the results on this item indicate that properties of zero have not been mastered by Grade 8 students. While the Panel judged the results of Item 12 as marginally satisfactory, it is not surprising that the students were evenly split between the correct answer and distractor D, since 0/6 is 0 and 6/0 cannot be simplified. It is rather surprising, however, that 14% of the students selected distractor C.

12. Simplify: $\frac{0}{6} =$

	Percent
A) 0	42
B) Infinity	3
C) 6	14
D) Cannot be done	36
E) I don't know	5

Figure 4-8: Grade 8 - Item 12

The Panel also stated that there seems to be an evident strength in the understanding of place value when dealing with whole numbers, but the strength is not as evident when dealing with rational numbers in decimal form. They expressed the opinion that fractions should be presented in many equivalent forms when they are taught.

Item 10, presented in Figure 4-9, was judged to be a weakness among Grade 8 students. While the answer is a fraction, it takes two steps to create the fraction. Of the students tested, 53% correctly took the number of boys as the numerator, but took the other number in the problem as the denominator. Too often, all that students do with a problem is take the numbers as they appear, combine them by a one-step process, and obtain an answer which is frequently the incorrect one.

18. There are 13 boys and 15 girls in a group. What fraction of the group is boys?

		Percent
A)	$\frac{15}{28}$	5
B)	$\frac{13}{15}$	53
C)	$\frac{15}{13}$	6
D)	$\frac{13}{28}$	32
E)	I don't know	2
	No response	1

Figure 4-9: Grade 8 - Item 18

Item 47, see Figure 4-10, was also judged as a weakness. From the data collected, what actually caused 38% of the Grade 8 students to select 2/3 as the answer cannot be determined. Several conjectures, however, can be made: two-thirds is the most commonly used fraction of the set of fractions presented, the students concerned themselves strictly with the relative magnitude of the denominator, the students could only apply the process of pair-wise comparisions of fractions, the students were not familiar with the process for computing decimal equivalents for the fractions or the importance of doing so. The weak performance on this item underscores the importance of recommendations 4-2 and 4-4.

47. Which number is largest?

		Percent
A)	$\frac{2}{3}$	38
B)	$\frac{4}{5}$	29
C)	$\frac{3}{4}$	16
D)	$\frac{5}{8}$	12
E)	I don't know	2
	No response	1

Figure 4-10: Grade 8 - Item 47

4.4.2 Comprehension of Measurement Concepts

Five items were used to measure acquisition of this objective. The results for the five items are presented in Table 4-15.

Table 4-15
Grade 8 Results (N = 42 250)
Objective: Comprehension of Measurement Concepts (mean = 69.4%)

Item No.	Measurement	Unit	% Correct	Panel Judgment
19	Temperature	Degree Celcius	69	Satisfactory
21	Capacity	Litre	84	Strength
22	Weight*	Kilogram	45	Satisfactory
23	Length	Centimetre	84	Very Satisfactory
43	Angle	Degree	65	Satisfactory

Four of the five items for this objective measured students' ability to select the appropriate metric measure. The fifth item, Item 43, dealt with measurement of angles.

The Panel found that the students were having little difficulty with the skills tested by the specific items. The Panel wondered if the metric concepts were being well-taught or if the generally good results were the result of out-of-school exposure to the material.

Item 22 yielded the lowest performance level for this objective. The Panel hypothesized that the low performance may have occurred because weight (mass) in metric units is not widely used in society at present. Lack of exposure may have caused the low performance.

22. A ten-year-old boy is likely to weigh:

	Percent
A) 35 grams	10
B) 75 grams	13
C) 35 kilograms	45
D) 75 kilograms	19
E) I don't know	12
No response	1

Figure 4-11: Grade 8 - Item 22

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* Though technically incorrect, the word 'weigh', not 'mass', was used on the test. It was deemed more advisable to run the risk of being criticized for using the familiar word 'weigh' than to use the decidedly unfamiliar, yet correct, term 'mass'.

On the other hand, Item 19 (see Figure 4-12) is an item on temperature, using degree Celsius as the unit. The degree Celsius was one of the first metric units to be introduced in Canada, but the result of this item is not very high.

19. The temperature on a sunny summer day would most likely be:

	Percent
A) 5° Celsius	5
B) 25° Celsius	69
C) 55° Celsius	12
D) 85° Celsius	9
E) I don't know	4
No response	1

Figure 4-12: Grade 8 - Item 19

The students' performance on metric length (Item 23) and metric capacity (Item 21) was very good, both 84%. The Panel did say, however, that as Canada goes metric these performance levels on the metric measurement items for this assessment may not be viewed so favourably on future assessments.

4.4.3 Comprehension of Geometric Concepts

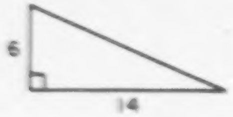
The students' ability on this objective was measured by four items. The results for the four items are presented in Table 4-16.

Table 4-16
Grade 8 Results (N = 42 250)
Objective: Comprehension of Geometric Concepts (mean = 53.8%)

Item No.	Percent Correct	Panel Judgment
38	69	Satisfactory
41	59	Marginally Satisfactory
52	24	Weakness
54	63	Satisfactory

The students' performance on Item 52 was the second lowest on the entire test. Forty-two percent of them simply multiplied the height of the triangle by the base and neglected to multiply that product by 1/2. Such an error is common when working with triangles. More surprising however is that 18% of the students selected distractor B. In other words, they added the height and base of the triangle. On Item 54, finding the volume of a box, 13% of the students added the dimensions instead of multiplying them.

52. Find the area of this right triangle.



		Percent
A)	42	24
B)	20	18
C)	84	42
D)	21	4
E)	I don't know	11
	No response	1

Figure 4-13: Grade 8 - Item 52

As the Panel stated in its summary comments, Geometry is considered important in everyday life. Perhaps the emphasis on basic arithmetic has contributed to the deterioration in the comprehension of geometric concepts. The difference between the mean percent correct for Computation with Whole Numbers and Comprehension of Geometric Concepts is exactly 30% (83.8% -vs- 53.8%). The Grade 8 student population in British Columbia appears to be fairly well drilled in computation with whole numbers but not so adept at comprehension of geometric concepts.

The Panel also wondered if teachers are postponing the teaching of geometry so that it gets done only if there is sufficient time in the year.

The Grade 8 students' performance on this objective was disappointing and the Panel's summary comment was that an overall weakness is evident. They felt that if geometry is to be considered important, then perhaps the approach and placement in the curriculum should be examined. Furthermore, they expressed the opinion that practical uses of geometry should be emphasized.

Recommendation No. 4-5: *Teachers should place greater emphasis upon the topics of geometry and measurement in their mathematics classes.*

4.4.4 Comprehension of Algebraic Concepts

The Grade 8 test contained three items designed to assess students' ability on this objective and two of these were repeated on the Grade 12 test. The Panel's comment that there were not sufficient items to adequately test this objective is well taken. However, no attempt was made to assess this objective in depth at any of the grade levels, and certainly not at Grade 4 and 8. The results of the three items are summarized in Table 4-17.

Table 4-17
Grade 8 Results (N = 42 250)
Objective: Comprehension of Algebraic Concepts (mean = 52.7%)

Item No.	Percent Correct	Panel Judgment
48	18	Weakness
56	72	Satisfactory
57	68	Satisfactory

The Panel felt the results were generally pleasing in this area for the Grade 8 level. Almost all of the Panel's comments dealt with the extremely low performance, the lowest on the test, on Item 48. Not surprisingly, Item 48 is also the item that yielded the second highest percent on the test (16%) of students selecting the "I don't know" distractor. The response of 156 which corresponds to (30-4) (8-2), was selected by 36% of the students tested and 20, which corresponds to (30-4)-(8-2), was selected by 25% of the students. Both distractors were selected more often than the correct one.

48. Simplify: $30 - 4(8 - 2) =$

	Percent
A) 0	2
B) 20	25
C) 156	36
D) 6	18
E) I don't know	16
No response	1

Figure 4-14: Grade 8 - Item 48

The Panel concluded from the results of Item 48 that the order of operations concept is not being learned and more emphasis should be placed upon it in Grade 7. More importantly, however, the Panel felt that an evaluation should be made concerning the importance of the order of operations concept and whether or not it should be in the curriculum at this level.

It should be noted that the order of operations concept was not only important enough to be placed in the proposed Core Curriculum by the Ministry of Education, but also the necessity of including an order of operation item from the assessment test was mentioned by all four Review Panels. It was in response to such suggestions that Item 48 was included on the test.

The Panel was satisfied with the performance on the other two items for this objective, Item 56 (evaluating an algebraic expression) and Item 57 (solving an equation).

Recommendation 4-6: If the order of operation concept is to remain a part of the curriculum of the elementary grades, then teachers must place more emphasis upon it.

4.5 Test Results: Applications Domain

For Grade 8, the Applications Domain had only two objectives, acquisition of which was measured by ten items. The discussion of the results for the Applications Domain is presented in this section organized by objective.

4.5.1 Solve Problems Involving Operations with Different Sets of Numbers

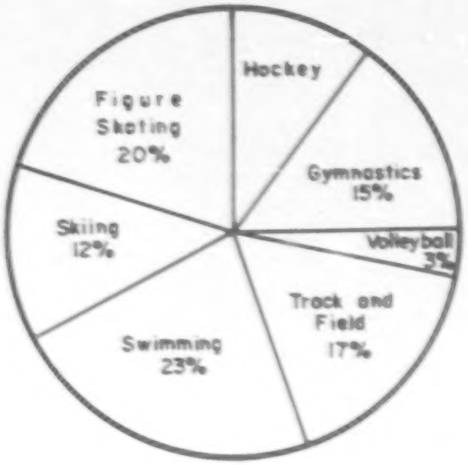
Seven items were designed to assess students' ability to solve problems involving operations with whole numbers, fractions, decimals, and percent. The results for those seven items are presented in Table 4-18.

Table 4-18
Grade 8 Results (N = 42 250)
Objective: Solving Problems Involving Operations
with Different Sets of Numbers (mean = 62.6%)

Item No.	Percent Correct	Panel Judgment
24	91	Strength
25	60	Satisfactory
26	63	Satisfactory
27	63	Satisfactory
58	66	Satisfactory
59	57	Satisfactory
60	38	Marginally Satisfactory

The students' performance on each of Items 25, 26, 27, 58, 59 was judged to be satisfactory. The Panel felt that perhaps the concept of arithmetic average, and the topic of circle graphs, should be given additional emphasis by teachers in Grades 7 and 8.

Items 58 through 60 were all based on the same circle graph, but only Item 60 is given below.



The 1200 students in a secondary school were asked to name their favourite Olympic sport. The results are shown in the circle graph above.

60. How many more students chose figure skating than gymnastics?

		Percent
A)	420 students	7
B)	35 students	19
C)	60 students	38
D)	5 students	24
E)	I don't know	10
	No response	1

Figure 4-15: Grade 8 - Item 60

As the Panel stated, the result on Item 60 was somewhat disappointing considering the different methods of solution available to students. Nineteen percent of the students simply added the percentages given and used the sum as the number of students. Twenty-four percent of them subtracted the percentages and used the difference as the number of students.

Item 24 is an excellent example of how well Grade 8 students can perform a one-step problem. For Item 24, the student multiplies the only two numbers provided and has the answer. The 91% performance level certainly represents a strength.

24. There are 25 members in the volleyball club. If the cost for each uniform is $24, how much would it cost to buy new uniforms for all the club members?

	Percent
A) $ 49	2
B) $6000	3
C) $ 600	91
D) $ 96	2
E) I don't know	2
No response	1

Figure 4-16: Grade 8 - Item 24

Recommendation 4-7: Teachers of mathematics at all levels must emphasize problem solving. Problem solving cannot be just one unit among many; it should be given high priority as being central to all aspects of mathematics. Students must have many experiences of solving multi-step problems and they should be taught to verify the reasonableness of their answers to problems.

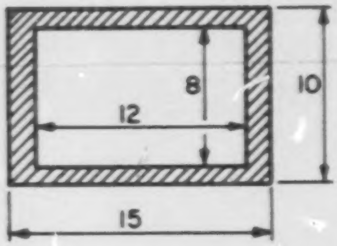
4.5.2 Solve Problems Involving Geometry and Measurement

Three items were designed to assess the Grade 8 students' ability to solve problems involving geometry and measurement. The results for the three items are presented in Table 4-19.

Table 4-19
Grade 8 Results (N = 42 250)
Objective: Solving Problems Involving Geometry and Measurement
(mean = 51%)

Item No.	Percent Correct	Panel Judgment
36	66	Very Satisfactory
37	27	Weakness
53	60	Marginally Satisfactory

As the Interpretation Panel pointed out, the performance of the students on Item 37, see Figure 4-17, is very disappointing. The Panel felt the low performance indicated the students lack an understanding of the concept of area. While the figure accompanying Item 37 was drawn to be as clear as possible, it may have still confused the students. However, the fact more students selected the area of the unshaded portion (96) as the answer than the correct answer would lend support to the belief that it was not the figure that caused the low performance. "I don't know" was selected by more students (21%) on Item 37 than any other item on the test.



37. What is the area of the shaded portion of this figure?

		Percent
A)	54	27
B)	96	28
C)	120	11
D)	60	11
E)	I don't know	21
	No response	1

Figure 4-17: Grade 8 - Item 37

The Panel was very satisfied with results for Item 36, especially because of the reading involved and the possible confusion introduced by using metric units. Though it is agreed that the performance level was very satisfactory, 11% of the respondents marked "I don't know" and 12% of the respondents marked 625 as the answer. Students selecting 625 as the answer combined the numbers provided with the wrong operation, multiplication instead of division.

The following quote from the Panel's report on the Grade 8 test serves as a good summary for this objective:

> "In summary, it was felt that the questions and answers (distractors) were generally well constructed, and that the students' responses were satisfactory, given the apparent low priority accorded problem solving. Problem solving, not merely 'word problems', and applications should be seen as a major focus or core of the Grades 4 through 8 curricula. Various models or strategies for problem solving should be emphasized strongly by teacher training institutions, and through in-service programs. This area of mathematics should be conveyed to teachers and students alike as being central to all of mathematics."

4.6 Grade 8 Reporting Categories

Mathematics achievement is the end result of the coalescing of a great number of student-based factors, both intrinsic and extrinsic. Attributes inherent in the student, programatic and curricular variables, as well as the effect of environmental variables such as teacher differences all contribute in varying and largely unknown degree to a given student's overall performance. Of the fairly large number of such variables which the conventional wisdom, current educational practice, and the endeavours of educational researchers have identified as being related to mathematics achievement, a limited number were selected for scrutiny in the Mathematics Assessment (see Chapter 1, Section 1.4).

A great deal more information concerning the relationship between certain personal background variables and achievement on the Mathematics Assessment test was collected than could possibly be reported in this volume. A more complete rendering may be found in the Technical Report dealing with test results which is obtainable from the Learning Assessment Branch. Researchers or others who wish to have access to the original data in order to seek answers to their own questions on issues relevant to the Mathematics Assessment should also direct their requests to the Learning Assessment Branch.

In the sections that follow, all of the results reported and recommendations made are based upon correlational trends. No attempt is made to imply that cause and effect relationships exist since the Mathematics Assessment was not designed to identify such relationships.

It remains for studies designed as follow-ups to the present one to seek to identify such relationships. Thus, while the assessment results show several fairly strong relationships between a student's sex and that student's achievement in mathematics, this does not imply that achievement in mathematics is determined by a student's sex. All that can be said on the basis of the assessment data is that there appears to be a relationship between the two variables.

For each of the reporting categories discussed in succeeding sections, reference is made to the various domains, objectives, and items evaluated in the Mathematics Assessment. For ease of reference, a labelling system for domains and objectives has been adopted and will be used throughout the remainder of this chapter. Each objective has been assigned a code number consisting of two digits separated by a period. For example, Objective 2.3 refers to Domain 2 (Comprehension), Objective 3 (Comprehension of Geometric Concepts). In Table 4-20, which follows, the rightmost column indicates the section of Chapter 4 where the Grade 8 population results for the appropriate objective were initially discussed.

Table 4-20
Grade 8: Code Numbers Used for Objectives

Code Number	Objective	Report Section for Population Results
1.1	Computation with Whole Numbers	4.3.1
1.2	Computation with Fractions	4.3.2
1.3	Computation with Decimals	4.3.3
1.4	Notation and Terminology	4.3.4
1.5	Knowledge of Geometric Facts	4.3.5
1.6	Equivalent Forms of Rational Numbers	4.3.6
2.1	Number Concepts	4.4.1
2.2	Measurement Concepts	4.4.2
2.3	Geometric Concepts	4.4.3
2.4	Algebraic Concepts	4.4.4
3.1	Arithmetic Problems	4.5.1
3.2	Geometry and Measurement Problems	4.5.2

4.6.1 Age

The graph displayed in Figure 4-18 presents a comparison of student performance on each objective for each of four age groupings: 15 years or older, 14 year olds, 13 year olds, 12 years or younger. On eleven of the twelve objectives, performance increases with a decrease in age up to the 13 year old. The 12 years and younger group's performance is less than or equal to the 13 year olds' performance on eleven objectives and about two percent greater on objective 3.2. The 15 years or older group's performance was an average of about eighteen percent below the provincial mean. While the performance of the 13 year old and 14 year old groups, representing over ninety percent of the population, have a much greater impact upon the provincial mean than those of the other groups, the relative position of each group is clearly implied by the data.

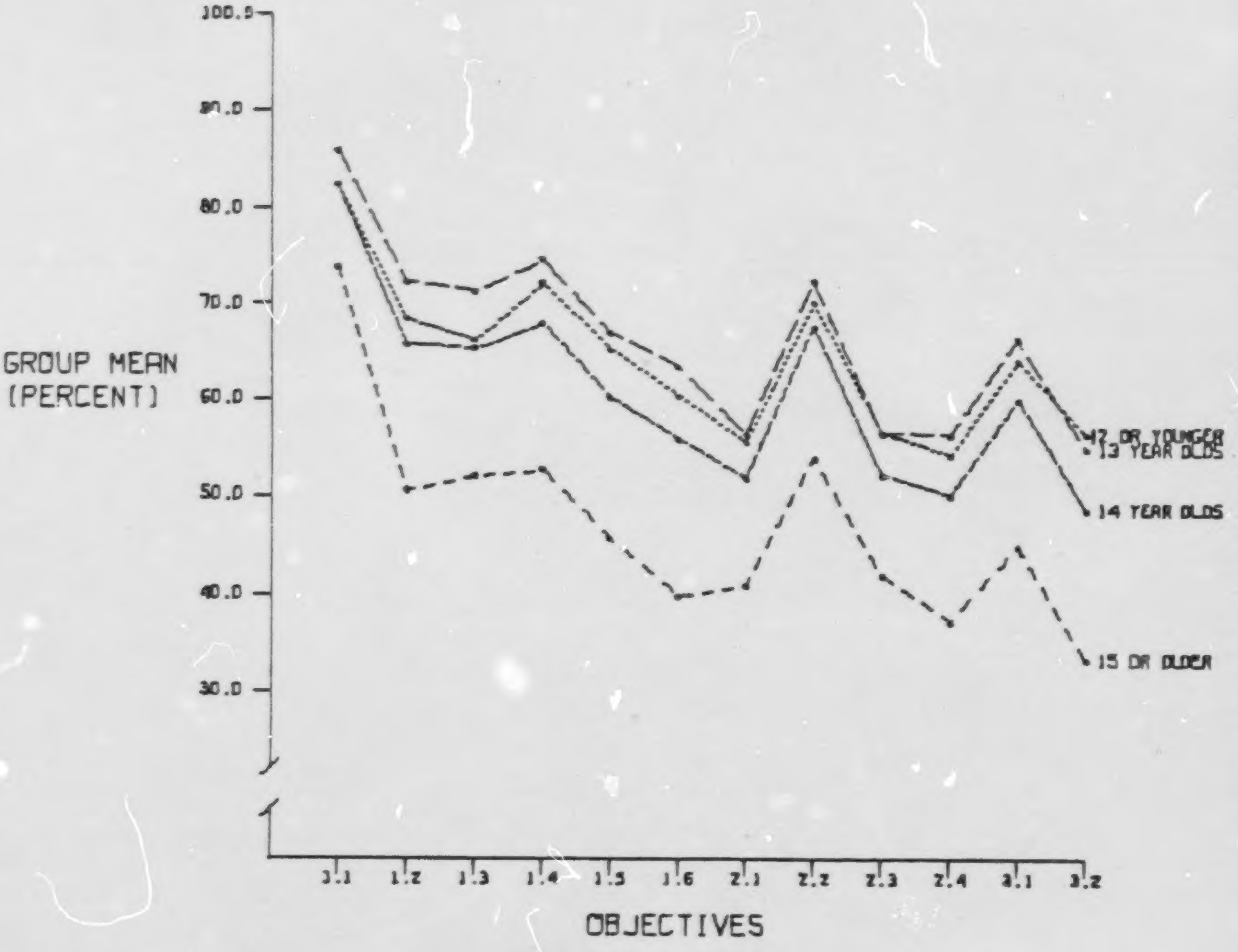


Figure 4-18:

4.6.2 Sex Differences

Both NLSMA and NAEP reported that girls outperformed boys only in those areas of mathematics such as computational skills which involve lower level cognitive behaviours. Based on such results one would expect the girls to outperform the boys in Domain 1, Computation and Knowledge, and the boys to outperform the girls on the other two domains. The data presented in Figure 4-19 supports the NLSMA and NAEP results quite clearly, although many of the differences are rather small in size.

Each group performed better than the other on six objectives, but of the six objectives on which the girls scored higher, five are in Domain 1, the lowest cognitive behaviour level.

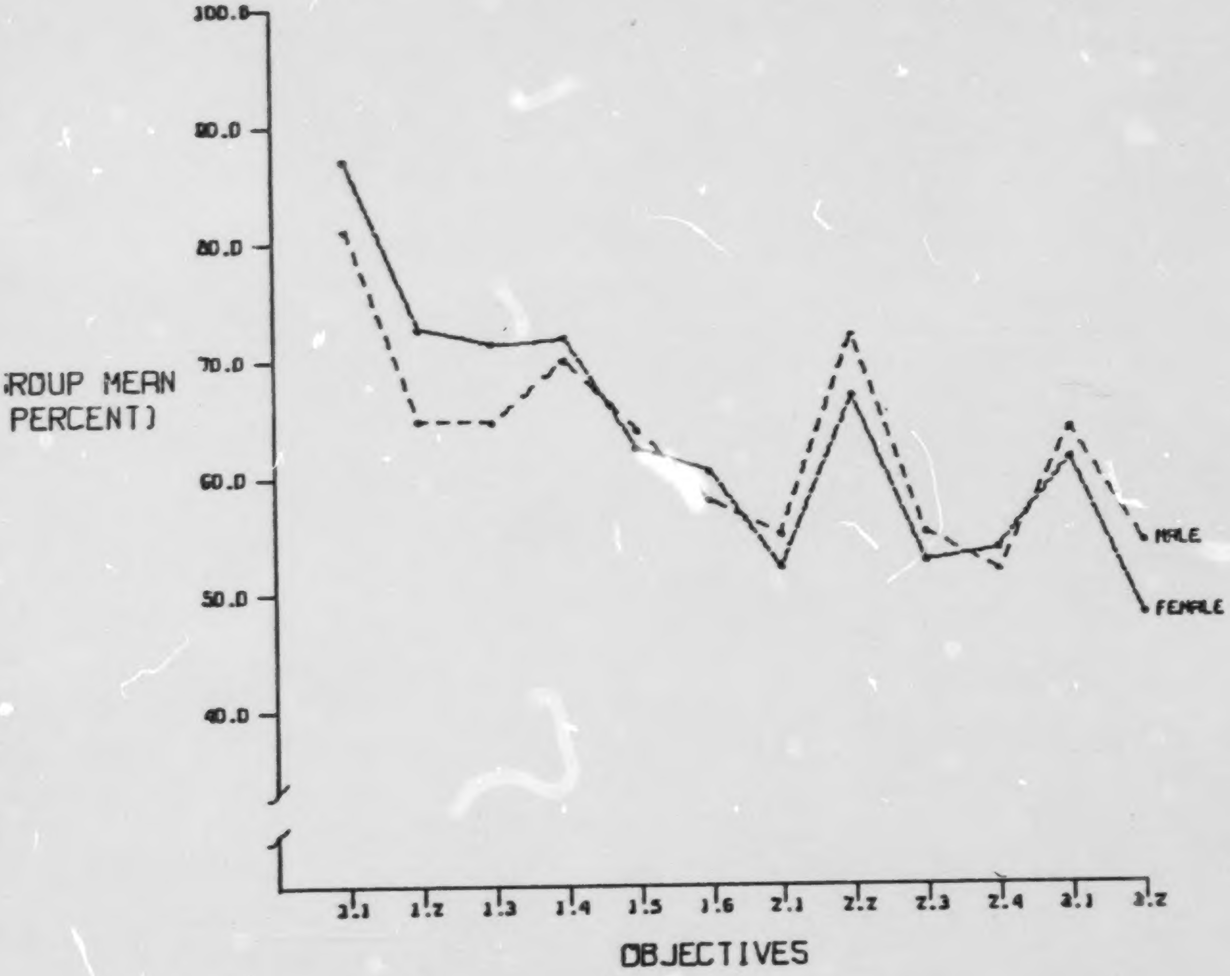


Figure 4-19: Grade 8 Results by Sex

4.6.3 Number of Schools Attended

The pattern of performance organized by the number of schools the students have attended is an extremely consistent one as shown in Figure 4-20. The performance among those who have attended eight or more schools is always lowest, the next lowest performance is by either the one-school group or the seven-schools group. The highest performance is achieved by the two-school group on every objective. The two-school group's performance is followed in order by the performances of the three-school group, then the four-school group, then the five-school group, and then the six-school group.

The performance always increases from the one-school group to the two-school group. From the two-school group to the six-school group, there is a consistent but slight decrease. The decrease in performance is then more pronounced for the seven-school group and the eight-or-more group.

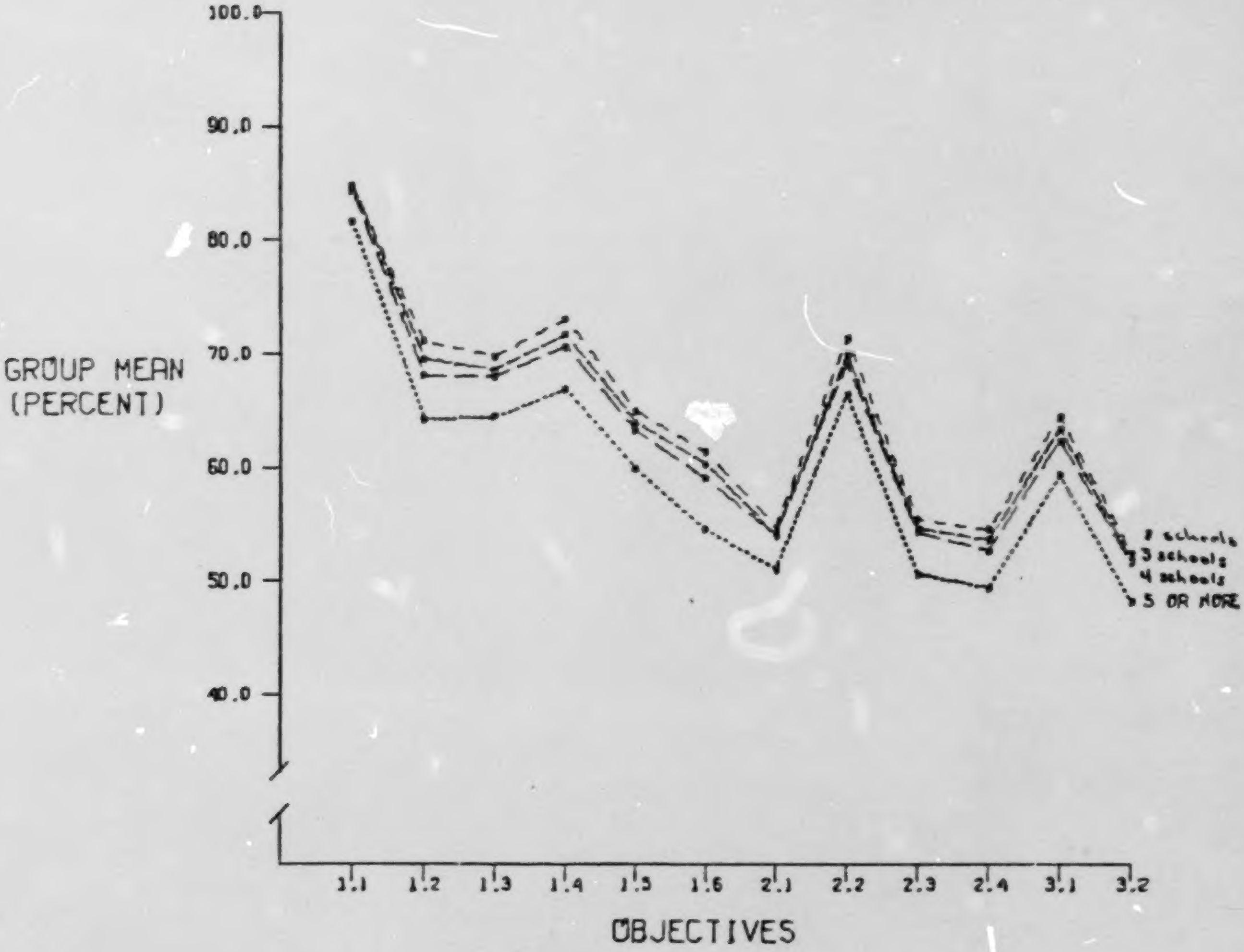


Figure 4-20: Grade 8 Results by Number of Schools Attended

4.6.4 Use of Hand-Held Calculators

Students were asked whether or not they used hand-held calculators at home, at school, or for homework. Figures 4-21 through 4-23 chart the assessment results for these three aspects of calculator use.

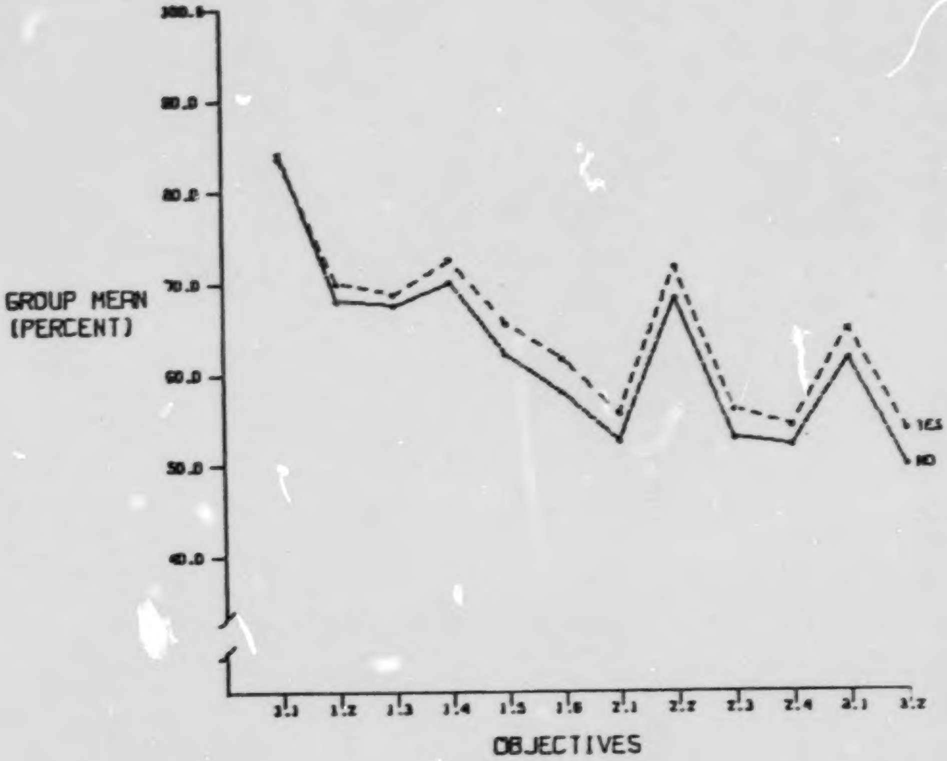


Figure 4-21: Grade 8 Results by Whether or Not a Student Uses a Hand-Held Calculator at Home

Those students who used a hand-held calculator at home outperformed the students who did not use a hand-held calculator at home on eleven of the twelve objectives. The non-users of calculators at home performed higher on Objective 1.1, Computation with Whole Numbers.

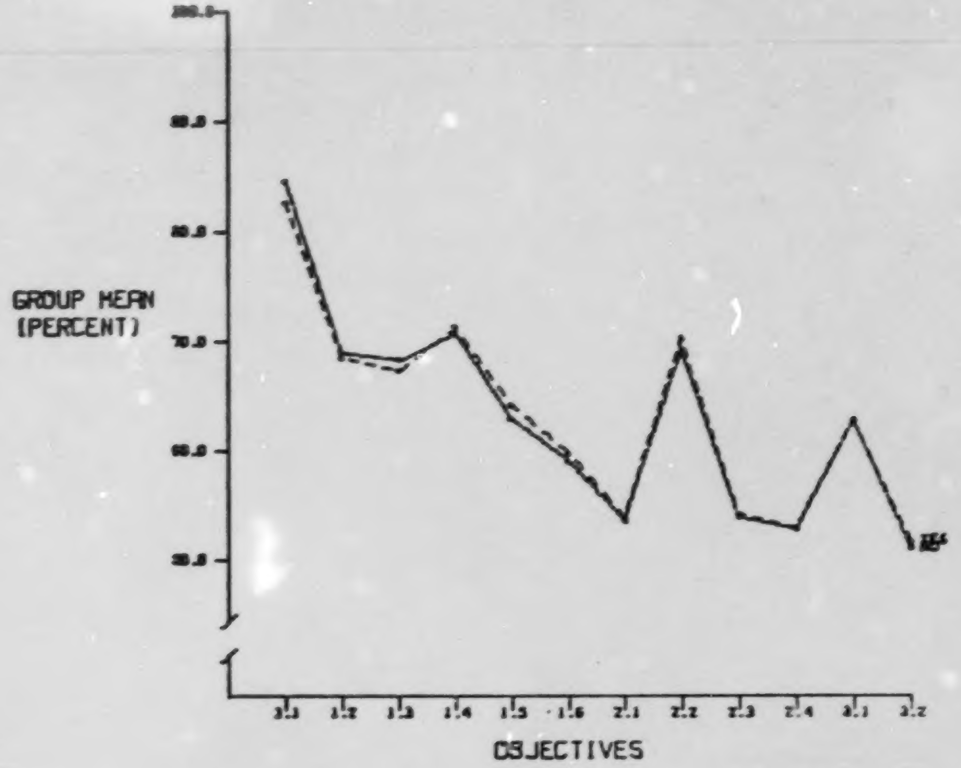


Figure 4-22: Grade 8 Results
by Use of Hand-Held Calculators for Homework

Students who used a hand-held calculator to do their homework outperformed non-users on eight of the twelve objectives; the two groups tied on Objective 3.1, and non-users outperformed the others on three objectives. Interestingly, the objectives on which the students who did not use a hand-held calculator for their homework scored higher were all computational objectives -- 1.1, Computation with Whole Numbers; 1.2, Computation with Rational Numbers in Fraction Form; and 1.3, Computation with Rational Numbers in Decimal Form.

For the category concerning whether or not the students used a hand-held calculator at school, the pattern is reversed and very consistent. The students who did not use a hand-held calculator at school outperformed the students who did on every objective.

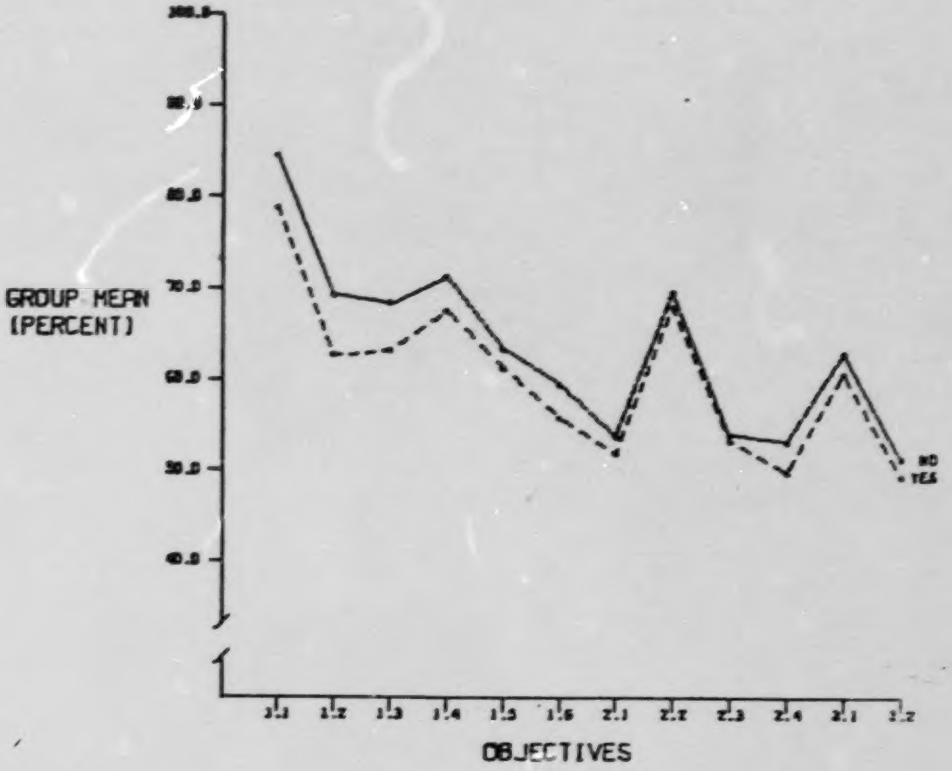


Figure 4-23: Grade 8 Results
by Use of Hand-Held Calculator in School

4.6.5 Time Spent on Assignments

The question concerning the amount of time spent on mathematics assignments outside of regular class was directed only to those students who had responded that they were taking a mathematics course at the time of the Mathematics Assessment. Of the 42 250 students who wrote the test 2 866, or about seven percent, responded that they were not taking a mathematics course. The breakdown of the data based on the amount of time spent on mathematics assignments outside of the regular class, i.e., homework, can be found in Table 4-7 of Section 4.2.7 of this chapter.

The performance patterns are very distinct when the data are presented graphically, as in Figure 4-24. The group that did spend some time, but less than thirty minutes a day, on mathematics homework outperformed the three other groups on every objective.

The belief that one cannot spend too much time on homework does not appear to be supported by these results, since the group spending more than sixty minutes a day scored lower than the other three groups on every objective. On the other hand, it may be that the poorer students simply take longer to complete the assignments. In any event, the performance of the thirty to sixty minutes a day group more closely paralleled the top group's performance, and the "none at all" group more closely paralleled the bottom group's performance.

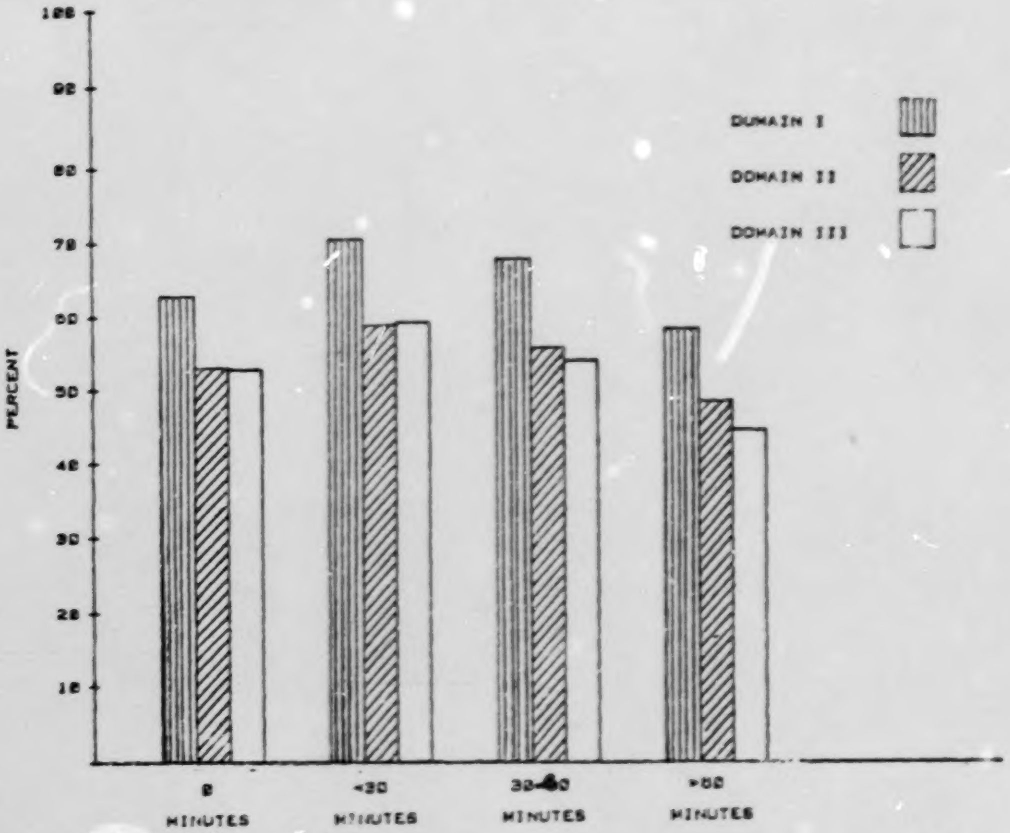


Figure 4-24: Grade 8 Results by Time Spent on Assignments

4.7 Reporting Categories from Reading Assessment

In addition to the Mathematics test, an assessment in Reading was also given at the Grade 8 level. These two tests contained similar, and in some cases identical, background information questions. On both the Mathematics and Reading tests, students were asked their birth date, sex, and number of schools attended. Using the common information, a computer search was able to match the complete reading and mathematics data for sixty-six percent of the students. A data file was created to contain the information and results on both tests for these matched students so that comparisons between their performances on the two tests could be made.

The new data file was used to obtain further information on student performance and to correlate certain aspects of student performance in mathematics with student performance in reading. In Section 4.6 of this report the data of the Mathematics Assessment for Grade 8 were organized according to certain reporting categories such as age, sex, and use of hand-held calculators. In this section the Mathematics Assessment data for Grade 8 are organized by two reporting categories obtained from the Reading Assessment.

Domain Two of the Reading Assessment was Comprehension as it was in the Mathematics Assessment. Correlations were computed on the Grade 8 Mathematics Assessment results for the four objectives of the Comprehension Domain and the two objectives of the Application Domain with the Reading Assessment results for the two objectives of their Comprehension Domain.

4.7.1 Reading Reporting Categories

The two reporting categories from the Grade 8 Reading Assessment which are presented in this section concern language groups and television watching. The three items shown in Figure 4-25 appeared on the Grade 8 Reading test.

1. Were you born in Canada?

   Yes . . . . ☐

   No . . . . ☐

2. Did you usually speak a language other than English before you started Grade 1?

   Yes . . . . ☐

   No . . . . ☐

3. Is English the language usually spoken in your home?

   Yes . . . . ☐

   No . . . . ☐

Figure 4-25: Place of Birth and Language Items from the Grade 8 Reading Assessment Test

The results for the three items were used to organize the Grade 8 students into five groups. The groups were defined as follows:

1. Non-Canadian, Non-English -- All Grade 8 students who responded "No" to Item 1, "Yes" to Item 2, and "No" to Item 3 in Figure 4-25.
2. Canadian, Non-English -- All Grade 8 students who responded "Yes" to Item 1, "Yes" to Item 2, and "No" to Item 3 in Figure 4-25.
3. First Generation Canadians -- All Grade 8 students who responded "Yes" to Item 1, "No" to Item 2, and "No" to Item 3 in Figure 4-25.
4. Non-Canadian, English -- All Grade 8 students who responded "No" to Item 1, "No" to Item 2, and "Yes" to Item 3 in Figure 4-25.
5. Canadian, English -- All Grade 8 students who responded "Yes" to Item 1, "No" to Item 2, and "Yes" to Item 3 in Figure 4-25.

Once the data were organized into the five groups, the results on each of the three domains for the Grade 8 Mathematics Assessment were computed. The five group averages for each domain are presented in Figure 4-26.

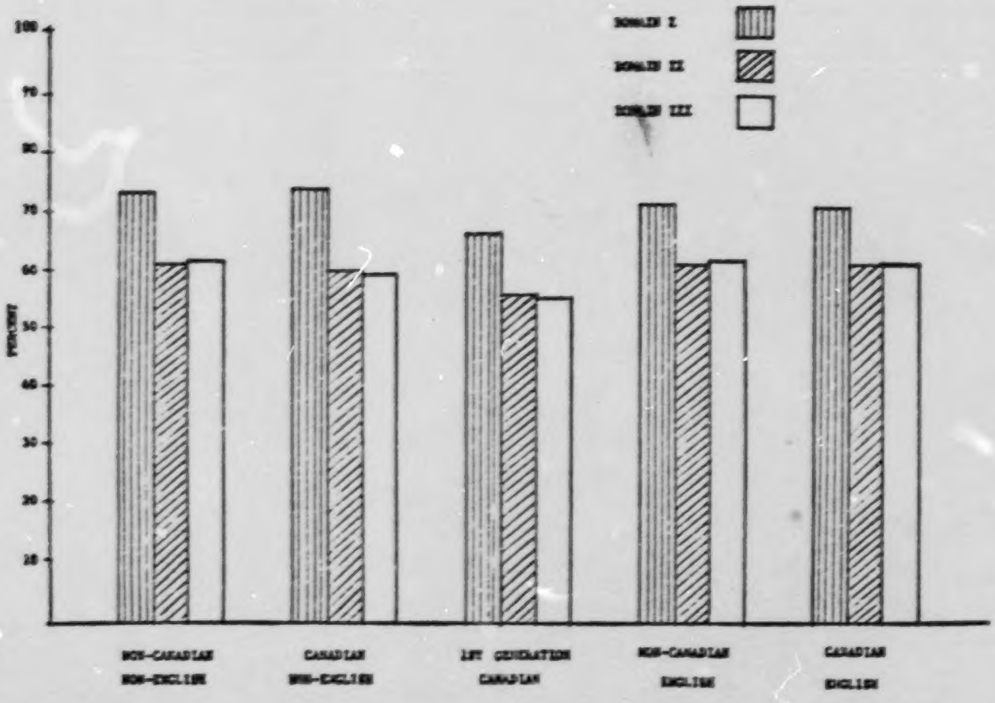


Figure 4-26: Grade 8 Results by Language Group

The Non-Canadian, non-English group of Grade 8 students obtained the highest score on all three domains. The first generation Canadian group scored lowest on all three domains. The middle three groups' average rankings were close together, differing by less than one percentage point. These results indicate that students who have a non-English speaking background perform well in mathematics and are certainly not disadvantaged in this respect.

Recommendation 4-8: Researchers should investigate the precise nature of the relationship between language background and achievement in mathematics.

The item shown in Figure 4-27 also appeared on the Grade 8 Reading Assessment test.

About how many hours of television do you
watch on an average day during the week?

Usually none . . . . ☐
Less than 1 hour . . . . . ☐
About 1 hour . . . . ☐
About 2 hours . . . . . . ☐
About 3 hours . . . . . . ☐
About 4 hours . . . . . . ☐
5 hours or more . . . . . . ☐

Figure 4-27: Television Watching Item
from the Grade 8 Reading Assessment

The Grade 8 results from the Mathematics Assessment were organized into seven groups based on the seven choices shown in the item in Figure 4-27. The results are presented in Figure 4-28.

The Grade 8 students who watched less than one hour of television per day during the week had the best performance followed closely by the about-one-hour group. The pattern among all of the groups is that the more television that is watched, the lower the performance on the Mathematics Assessment. The non-television group's performance was about midway between the about-three-hours and the about-four-hours groups.

The pattern exhibited in the Grade 8 results is very different from the pattern that existed in the Grade/Year 4 data, as presented in Section 3.6 of this report.

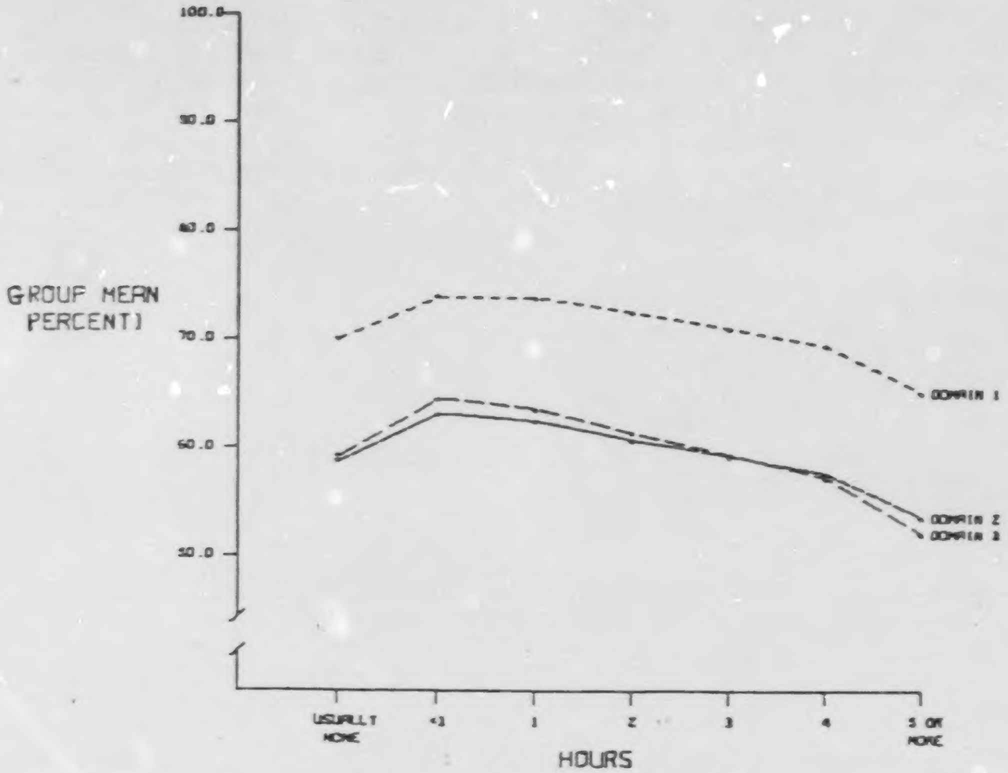


Figure 4-28: Grade 8 Results by Television Watching

4.7.2 Correlation of Reading Results with Mathematics Results

Domain Two of the Reading Assessment was entitled Comprehension as was Domain Two of the Mathematics Assessment. Both tests attempted to assess comprehension of their respective content areas. To see if there was a relationship between scores in reading and scores in mathematics, correlations were computed between the four objectives of Domain Two of the Mathematics Assessment and the two objectives of Domain Two of the Reading Assessment.

Since all the items, except one, of the Applications Domain of the Mathematics Assessment required a great deal of reading compared to the other test items, correlations between the two objectives of Domain Three of the Mathematics Assessment and the two objectives of Domain Two of the Reading Assessment were also computed. All twelve correlations are presented in Table 4-21.

Table 4-21
Grade 8: Correlations of Reading and Mathematics Results

Reading Objectives	Mathematics Objectives 2.1	2.2	2.3	2.4	3.1	3.2
2.1	0.36	0.33	0.33	0.32	0.43	0.39
2.2	0.39	0.33	0.33	0.31	0.43	0.39

The test to determine if a correlation is significantly different from zero is dependent upon the size of the sample. Given a sample of size 27 847, a correlation of 0.02 or greater would be statistically significantly different from zero. Hence it is more appropriate to talk of educational significance. Glass and Stanley present the following categorization of correlations: if the correlation is less than or equal to 0.2 then it should be considered weak; if the correlation is between 0.2 and 0.6, then it should be considered of moderate strength; if the correlation is greater than or equal to 0.8, then it should be considered strong.

All of the correlations in Table 4-21 are of moderate strength. Within a domain the correlations are very consistent and between the two objectives of the Reading Assessment the correlations are very consistent. The correlations for the four objectives of Domain Two of the Mathematics Assessment differ by only 0.08 and half of the correlations are 0.33. Of the correlations for each mathematics objective with the two corresponding reading objectives, four are identical. The correlations for Domain Three average about 0.07 greater than the correlations for Domain Two.

4.8 Summary and Recommendations

The Grade 8 test consisted of sixty items measuring acquisition of twelve objectives in three domains. In addition to the content items, the test contained ten items dealing with student background information. Both the content and background information items were presented in multiple choice format. Every content item had five foils or distractors of which four were possible answers, while the last was "I don't know". Students responded to the test items by marking their response on a mark-sense card which had been specially designed for the Grade 8 Mathematics Assessment.

The background information also showed that over ninety-five percent of the Grade 8 students spent one hour or less per day on mathematics homework and that about fifteen percent of these spent no time at all on mathematics homework. Almost thirty percent of the students had used a hand-held calculator for homework.

4.8.1 Background Information

Based upon the data gathered from the ten background information items, over ninety percent of the Grade 8 students were within the normal age range expected and 1300 more boys than girls took the test. Almost one out of every four students had already attended five schools while less than a third of the students had attended only two schools, presumably one elementary school and one secondary school. Over two-thirds of the students were attending non-semestered schools and almost ninety percent were enrolled in Math 8 at the time of the administration of the test.

The background information also showed that over ninety-five percent of the Grade 8 students spent one hour or less per day on mathematics homework and that about fifteen percent of these spent no time at all on mathematics homework. Almost thirty percent of the students had used a hand-held calculator for homework.

4.8.2 Test Results

In the Computation and Knowledge Domain, Grade 8 students performed satisfactorily on computation with whole numbers, common fractions, and decimal fractions. They also performed satisfactorily on the items for Knowledge of Notation and Terminology and Knowledge of Geometric Facts.

The poorest performance by Grade 8 students in Domain 1 was with Equivalent Forms of Rational Numbers. While they did not have any particular difficulty changing a common fraction to an equivalent common fraction, they did have difficulty changing a common fraction to an equivalent decimal fraction and to a percent.

The students' performance on items from the Comprehension Domain was mixed, with both strengths and weaknesses being noted. The weaknesses were with items concerning basic fraction concepts, selecting the largest common fraction from a list, and finding the area of a right triangle. The lowest performance on the entire test was on the order of operations item in the Comprehension Domain.

The strengths noted in the Comprehension Domain were with items concerning place value with whole numbers and the metric units of capacity. Students also performed well on the item concerning the metric units of length.

Grade 8 students also performed at a satisfactory level on the items of the Applications Domain. The only weakness indicated was with one item dealing with area. They performed very well on a word problem involving whole number multiplication and on a word problem involving whole number division.

4.8.3 Reporting Categories

Mathematics achievement is the end result of the coalescing of a great number of student-based factors, both intrinsic and extrinsic. Attributes inherent in the student, programatic and curricular variables, as well as the effect of environmental variables such as teacher differences all contribute in varying and largely unknown degrees to a given student's overall performance. Of the fairly large number of such variables which the conventional wisdom, current educational practice, and the endeavours of educational researchers have identified as being related to mathematics achievement, the ones selected for scrutiny in the Grade 8 Mathematics Assessment were age, sex, number of schools attended, use of hand-held calculators, and time spent on mathematics homework.

Age Differences -- On eleven of the twelve objectives, the performance generally increased with a decrease in age. The performance of the twelve years or younger group was not as good as the thirteen year olds' but it was never less than that of the fourteen year olds. The fifteen years or older group's performance was an average of about eighteen percent below the provincial mean.

Sex Differences -- Each group performed better than the other on six of the objectives, but of the six objectives on which the girls obtained the higher performance, five were in Domain One.

Number of Schools Attended -- Those Grade 8 students who had attended two schools performed better than all of the other groups on every objective. The pattern exhibited was that the fewer schools attended, the higher the performance. The single exception to this pattern was the one school group which had the second lowest performance on eight of the twelve objectives.

Use of Hand-Held Calculators -- Students who used a hand-held calculator at home outperformed the students who did not use a hand-held calculator at home on eleven of the twelve objectives. Students who used a hand-held calculator to do their homework had higher performance than the non-users on eight of the twelve objectives. The two groups tied on Objective 3.1, and the non-users' performance was higher on three objectives. Interestingly, those three objectives on which the performance was higher for those students who do not use a hand-held calculator for their homework were all computational objectives. For the category concerning whether or not Grade 8 students used a hand-held calculator at school, the pattern was reversed and very consistent. Students who did not use a hand-held calculator at school outperformed the students who did on every objective.

Time Spent on Homework -- The group that did spend some out-of-class time on mathematics assignments, but less than thirty minutes per day, outperformed the three other groups on every objective.

4.8.4 Data From the Reading Assessment

In addition to the mathematics test, an assessment test in Reading was also given at the Grade 8 level. These two tests contained similar, and in some cases identical, background information questions. On both the Mathematics and Reading tests, students were asked their birth date, sex, and number of schools attended. Using the common information, a computer search was able to match and complete reading and mathematics data for sixty-six percent of the Grade 8 students. A data file was created to contain the information and results on both tests for the matched students so that comparisons between their performances on the two tests could be made. The two reporting categories which were presented from the Grade 8 Reading Assessment concerned language and television watching.

Language -- The Grade 8 data were grouped according to whether the students had been born in Canada, whether they usually spoke a language other than English before starting Grade 1, and whether English was the language usually spoken in the home. The results showed the performance of the non-Canadian, non-English group to be the best overall.

Television Watching -- Grade 8 students who watched some but less than one hour of television per day during the week had the best performance followed closely by the group that watched television about one hour per day. The pattern among all the groups was that the more television watched, the lower the performance. The no-television group ranked about midway between the about-three-hours and about-four-hours groups.

4.8.5 Recommendations

Based on the data presented in this chapter, the following recommendations were made.

Recommendation 4-1: Due to the increasing importance of the decimal form of rational numbers, all teachers of mathematics should take special care to lay the foundation for understanding of the expansion of the numeration system to the decimal form of rational numbers. Understanding of the decimal form of rational numbers should then be used to improve performance with the four basic operations using the decimal form of rational numbers.

Recommendation 4-2: In future materials produced by authors and curriculum developers, the decimal form of rational numbers should precede the fraction form. The overall curriculum should place much greater emphasis on the decimal form.

Recommendation 4-3: Classroom teachers and those involved in the training of mathematics teachers should emphasize the importance of instruction in geometry in the elementary school mathematics curriculum, and show future teachers the place geometry holds in both mathematics and everyday life.

Recommendation 4-4: Teacher of mathematics should emphasize the area of equivalent forms of rational numbers. Students need many experiences of starting with a rational number in fraction form, decimal form, or percent form and writing it in the other two forms.

Recommendation 4-5: Teachers should place greater emphasis upon the topics of geometry and measurement in their mathematics classes.

Recommendation 4-6: If the order of operations concept is to remain a part of the curriculum of the elementary grades, then teachers must place more emphasis upon it.

Recommendation 4-7: Teachers of mathematics at all levels must emphasize problem solving. Problem solving cannot be just one unit among many; it should be given a high priority as being central to all aspects of mathematics. Students must have many experiences of solving multi-step problems and they should be taught to verify the reasonableness of their answers to problems.

Recommendation 4-8: Reseachers should investigate the precise nature of the relationship between language background and achievement in mathematics.

Chapter 5

GRADE 12: RESULTS, INTERPRETATION, AND RECOMMENDATIONS

The results obtained on the Grade 12 Mathematics Assessment test are presented and discussed in this chapter for each objective and for each item tested. Some of the actual items from the assessment instrument are included as illustrative examples in order to clarify points made in the discussion. Space limitations have made it impossible to include every item in the present report. A companion volume in this series, Report Number 3: Technical Report, contains summary information about every item on each of the three tests. Copies of the Technical Report may be obtained upon request from the Learning Assessment Branch, Ministry of Education.

5.1 Description of the Test

The Grade 12 test consisted of seventy-two items designed to assess students' mastery of eleven objectives grouped into the three domains of Computation and Knowledge, Comprehension, and Applications. In addition to the mathematics items, the test contained fifteen background information items which students were asked to complete before taking the test.

Students responded to all items on the test by shading in the appropriate area on mark-sense cards which were specifically designed for this test. All items on the test were of the multiple-choice variety. For each item, five foils were given. Of these, four were possible answers to the item and the fifth was "I don't know".

One and one-half hours were allotted for the test: thirty minutes for instructions, distribution and collection of the test booklets, and completion of the background information items; sixty minutes for completion of the test itself.

5.2 Description of the Population

The Grade 12 test was designed to be written by all students enrolled in Grade 12, regardless of their mathematics backgrounds. According to statistics released by the Ministry of Education the enrolment in Grade 12, as of February 28, 1977, was 32 532. Of this number, 23 136 (or 71.1% of the total) wrote the test.

5.2.1 Non-Response and Frivolous Response Data

For 1975-76, the most recent year for which such figures are available, the absenteeism rate for senior secondary schools in the province was calculated to be approximately 10%. In spite of the fact that many observers believe this figure to be a conservative estimate of the true rate of absenteeism, the fact remains that a sizable proportion of Grade 12 students was not present for the test and that the proportion of non-respondents exceeds the normal absenteeism rate.

The National Assessment of Educational Progress (NAEP) program in the United States has encountered similar difficulties of non-participation. In their first analyses, they assumed that the non-response group was similar in composition to the whole population and that those individuals' failure to participate would not affect the overall item results in any way. Subsequent studies have shown that the non-response group is not exactly similar in composition to the response group and that failure to take the non-response group into account in interpreting the assessment data could result in artificially high success rates being reported on items and objectives. NAEP has stated that the extent of this inflation is almost certainly not great enough to affect decision-making. For example, a success rate of 67% achieved by those responding to the test might represent a true success rate of 64% for the entire population.

The non-response problem was also studied for its impact upon the B.C. Mathematics and Reading Assessments. As part of the background information questionnaire on both instruments, students were asked to supply their date of birth, sex, number of schools attended, and school code number. On this basis, 63% of the completed mathematics tests at the Grade 12 level were uniquely matched with completed reading tests. The remaining mathematics tests had either no counterpart or more than one counterpart in reading or else there was more than one mathematics test which had the same answers to the four items upon which the matching was based.

The results obtained on the mathematics test by those students who had completed both the reading and the mathematics tests were compared to results obtained by those who completed only the mathematics test. This examination showed that the latter group lowered the success rate by an average of less than one percent on an item. If we assume that the group who did not write the mathematics test is similar to the group who wrote only the mathematics test, then this information tells us that the assessment results have not been unduly affected by the failure of the non-response group to complete the Mathematics Assessment instrument.

Another matter which was a cause of some concern at this level was that of students responding frivolously on the test. It was felt by some that since individual students were not to be identified and since individual student scores were not to be reported, some students would make a mockery of the test and either select answers at random, guess, or in some other way respond frivolously to the items on the test. Two measures were undertaken in an effort to gauge the extent of such behaviour on the part of students taking the test:

Firstly, each completed mark-sense card was hand checked for completeness and for obvious patterns of frivolous response, such as the constant use of a single response category or the repetition of a series of responses: ABC ABC ABC..... Thirty-two such instances (0.1% of the total) were found. Secondly, a computer analysis was undertaken to identify those students who had, in all likelihood, responded by guessing or by selecting answers at random. Since each item had five foils, all those students who had fewer than 20% of the items correct may have responded frivolously. In all, 208 such cases were found.

In summary, the best data available at this time lead to the conclusion that, despite the fact that a sizable proportion of the Grade 12 population failed to take the Mathematics Assessment test, the overall results obtained are an accurate representation of the total population. Moreover, analysis of individual students' response patterns has failed to turn up any evidence of widespread lack of due care and attention in completing the test.

5.2.2 Distribution by Sex

There were approximately 800 more girls than boys who took the Mathematics Assessment test. The percents represented in Table 5-1 correspond fairly well with the data on sex distribution collected by the Ministry of Education which shows the Grade 12 population to be 49% male and 51% female.

Table 5-1
Grade 12: Sex of Respondents

Sex	Frequency	Percent
Male	11 069	47.8
Female	11 831	51.1
No Response	202	0.8
Multiple Response	34	0.1

Further analysis of this variable was conducted, taking into account the highest level of mathematics completed or being completed by the respondent. The data shown in Table 5-2 illustrate the fact that females are under-represented in senior mathematics classes. Although they constitute 51% of the Grade 12 population as a whole, they account for only 43% of the enrolment in Math 12. On the other hand, they form close to 65% of the group which takes no mathematics beyond Math 10, the last compulsory mathematics course. Less than one third of the female students have taken Math 12, while almost half the males have done so.

Table 5-2
Grade 12: Percent Distribution of Mathematics Background by Sex

	Last Mathematics Course Taken or Being Taken:		
	Math 12	Math 11	Math 10
Male	56.7	45.1	34.5
Female	42.5	53.9	64.2
No Response	0.5	0.7	0.9
Multiple Response	0.1	0.1	0.2

Recommendation 5-1: The Ministry of Education should institute a program of research designed to ascertain why such a high proportion of female students do not continue to study mathematics beyond the last compulsory course.

Recommendation 5-2: On the basis of the evidence obtained as a result of the implementation of Recommendation 5-1, the Ministry of Education, in cooperation with local school districts and teachers' groups, should institute professional development programs to sensitize teachers and counsellors to this tendency and with ways of dealing with it.

5.2.3 Age of Respondents

The assessment instrument was administered during the month of March 1977. As is shown in Table 5-3, there was a fairly broad range of ages represented among those responding.

Table 5-3
Grade 12: Age of Respondents

Age	Frequency	Percent
21 or older	57	0.2
20	277	1.1
19	1 055	4.5
18	7 127	30.8
17	13 993	60.4
16	419	1.8
15	36	0.1
14 or younger	22	0.0
No Response	150	0.6

Students were asked to provide the day, month and year of their birth on the response card. Those at either extreme, but particularly those reported as being less than fifteen years old, may have marked the wrong year since it seems unusual that 22 fourteen year olds would be completing Grade 12.

5.2.4 Number of Schools Attended

As with Grades 4 and 8, the data on number of schools attended by students in Grade 12 reflect a high degree of mobility among the general population.

Table 5-4
Grade 12: Number of Schools Attended

Number	Frequency	Percent
1	335	1.4
2	2 602	11.2
3	6 304	27.2
4	5 231	22.6
5	3 339	14.6
6	2 020	8.7
7	1 218	5.2
8 - 9	939	4.0
10 or more	917	3.9
No Response	101	0.4
Multiple Response	70	0.3

By the time students reach this level, they would normally have attended a minimum of two schools: an elementary school and a secondary school. The results summarized in Table 5-4 indicate that only about 12% of these students had attended two or fewer schools since starting Grade 1. They also show that 15% of the students have attended at least seven schools and that approximately 4% have attended ten or more schools. Such students have changed schools almost every year.

5.2.5 Semestered versus Non-Semestered Courses

Almost 60% of the students responded affirmatively to the question, "Is the mathematics course you are now taking (or was the mathematics course you have most recently taken) a semestered course?" This is almost the reverse of the situation at Grade 8 level, where 68% reported that their mathematics course was non-semestered.

Table 5-5
Grade 12: Percent of Semestered vs Non-Semestered Courses

	TOTAL	Math 12	Math 11	Math 10
Semestered	59.1	61.7	60.9	48.1
Non-Semestered	39.0	37.1	37.3	49.4
No Response	1.4	0.6	1.4	2.0
Multiple Response	0.3	0.4	0.3	0.3

As the data in Table 5-5 indicate, about 62% of the Math 12 students are taking or have taken the course in one semester rather than over the entire school year. On the other hand, only 48% of the students whose last mathematics course was Math 10 took a semestered course at that level.

5.2.6 Highest Level of Mathematics Completed

Since the Mathematics Assessment test was written in the spring and not at the end of the term, Grade 12 students were asked both what was the last mathematics course which they had successfully completed as well as the name of the mathematics course which they were taking at the time, if any. A fairly accurate picture of the mathematics background with which these people are leaving the public schools may be obtained by combining the data obtained from these two questions.

The data show that just over 80% of the students take at least one mathematics course beyond the Grade 10 level, which is the last year in which the study of mathematics is compulsory. Unfortunately, it is not possible to tell from this information what factor or factors may be at work to influence students to continue their studies of mathematics. Among the possible factors are the admission requirements to university but, as will be seen later (section 5.2.10), only slightly more than 30% of the students have decided to continue their education at the post-secondary level in academic programs.

Table 5-6
Grade 12: Highest Level of Mathematics Attained

Course	Percent
Math 10	15.1
Math 11	45.8
Math 12	37.1

5.2.7 Part-Time Employment

The data collected regarding the question of part-time employment show that over 50% of Grade 12 students are involved in such activities. The majority of such students work at their part-time jobs both during the week and on weekends. Students who had no such employment did not respond to this item.

Table 5-7
Grade 12: Part-Time Employment

No. of Hours/Week	Frequency	Percent
1-5	1 136	4.9
5-10	3 518	15.2
10-20	5 232	22.6
More than 20	2 444	10.5
No Response	10 784	46.6
Multiple Response	22	0.0

The rate of students' involvement in part-time employment appears to be independent of their mathematics backgrounds. Of the students enrolled in Math 12, 53.2% indicated they had part-time jobs. For those whose last course was Math 11 or 10, the figures were 54.8% and 51.1% respectively.

5.2.8 Use of Hand-Held Calculators

Students were asked to respond to three questions concerning the extent and nature of their use of hand-held calculators. The data obtained from their responses are summarized in Table 5-8.

For each category of use, about one-half of the students indicated that they had at some time employed a calculator. However, when these data were examined in the light of mathematics background, some interesting comparisons became apparent. In the Math 12 group, almost 75% said they have used a calculator in school, whereas only 29% of the Math 10 group had done so. Similarly, almost 80% of the Math 12 group had used a calculator for homework, but only 34% of the Math 10 group had done so.

Table 5-8
Grade 12: Use of Hand-Held Calculators (Percents)

	Do You Use a Hand-Held Calculator: At Home?	For Homework?	in School?
Yes	50.6	55.7	51.2
No	48.0	42.7	47.4
No Response	0.8	1.1	1.1
Multiple Response	0.4	0.3	0.1

The possible applications and educational impact of the use of hand-held calculators in school are areas that require intensive research and development initiatives. Teachers and curriculum developers require assistance in identifying areas of the curriculum suited to calculator applications and in developing appropriate curricular materials.

Recommendation 5-3: Curriculum Development Branch should consider the impact of the use of hand-held calculators in mathematics classrooms at various levels: primary, intermediate, junior secondary, and senior secondary. They should provide guidance and directions to teachers of mathematics regarding the most appropriate uses of such calculators in their teaching.

5.2.9 Parents' or Guardians' Academic Backgrounds

Grade 12 students were asked to report on the highest level of schooling attained by their parents or guardians. The information concerning this item is summarized in Table 5-9.

Table 5-9
Grade 12: Highest Level of Education Attained by Parents or Guardians

	Mother or Guardian		Father or Guardian	
	Frequency	Percent	Frequency	Percent
Elementary	1 887	8.1	2 639	11.4
Junior Secondary	4 558	19.7	4 377	18.9
Senior Secondary	7 342	31.7	4 495	19.4
Trade School	1 767	7.6	2 258	9.7
Technical or Some University	2 256	9.7	2 215	9.5
Bachelor's Degree	906	3.9	1 247	5.3
Graduate Degree	654	2.8	1 278	5.5
I Don't Know	3 436	14.8	4 176	18.0
No Response	330	1.4	358	1.5
Multiple Response	0	0.0	93	0.4

5.2.10 Future Plans

The data regarding students' plans for the immediate future are presented in Table 5-19 in percentage terms. Results are reported for the population as a whole as well as for three subgroups determined by the students mathematics backgrounds. "Math 12" refers to students who have taken or are taking Mathematics 12, "Math 11" and "Math 10" refer to the corresponding groups of Grade 12 students for whom some form of Mathematics 11 or of Mathematics 10 was the highest level successfully completed.

Table 5-10
Grade 12: Students' Future Plans (Percents)

	Total	Math 12	Math 11	Math 10
Go to work	19.2	7.2	23.8	34.2
Business school	1.9	0.8	2.5	2.9
Vocational, Art or Trade Training	9.1	4.1	12.0	12.4
Technical Institute	6.3	9.8	4.8	2.8
Community College: Pre-University	10.1	14.5	9.0	3.8
Community College: Career Programme	7.9	5.3	9.5	9.6
University	21.1	40.5	11.8	3.2
Other	9.1	5.2	10.4	13.7
Undecided	13.4	11.4	14.5	15.0
No Response	0.9	0.4	0.8	1.1
Multiple Response	0.4	0.3	0.4	0.8

Several trends are clearly discernible from the data. A large proportion of the Math 12 group, 55% to be exact, expect to enroll either in pre-university programs at community colleges or in university. On the other hand, only 7% of the Math 10 group had similar plans. Only 7% of the Math 12 group plan to enter the labour market upon completion of secondary school, whereas almost 35% of the Math 10 group plan to do so. In all three subgroups, between ten and fifteen percent have yet to decide upon their future plans.

5.3 Test Results: Knowledge and Computational Domain

The seventy-two mathematics content items were divided among eleven objectives, with the objectives being grouped into three domains: In this section the results for the Computatation and Knowledge domain are reported for each objective and for each item. The following information is provided for each objective:

1) the item numbers pertaining to that objective;
2) the percent of students who obtained the correct answer;
3) the judgment of the Interpretation Panel concerning the acceptability of the result.

5.3.1 Computation with Fractions

The test contained four items involving computation with rational numbers expressed in fraction form, one item for each of the four basic operations of addition, subtraction, multiplication, and division. The results are summarized in Table 5-11.

Table 5-11
Grade 12 Results (N = 23 136)
Objective: Computation with Fractions (mean 83.3%)

Item No.	Operation	Percent Correct	Panel Judgment
2	Addition	86	Satisfactory
6	Subtraction	86	Very Satisfactory
11	Division	74	Satisfactory
29	Multiplication	87	Very Satisfactory

The Interpretation Panel found these results to be quite satisfactory. They considered the items to be relatively easy and recommended the inclusion of items involving mixed numbers on future assessment tests at this level.

It is true that the items used were easy, although they did involve most of the major concepts and skills required to perform the operations. The exercises used were: $\frac{1}{2} + \frac{1}{3}$, $\frac{2}{5} - \frac{1}{3}$, $\frac{2}{3} \div \frac{5}{7}$, and $\frac{3}{4} \times \frac{5}{7}$. Had the items been more difficult, e.g., $4\frac{3}{8} - 2\frac{5}{12}$, it would not be as clear whether the students' incorrect responses were due to the difficulty of the item or to the students' inability to use the appropriate algorithm. These results indicate that, as a group, Grade 12 students are able to perform the basic operations on fractions.

The fact that students' performance in division of fractions is some 12% lower than their performance on the other three operations, is not surprising. The algorithm frequently taught for this operation ("invert and multiply") is difficult to make meaningful, the operation is rarely used, and students get relatively little practice in using the operation.

5.3.2 Computation with Decimals

The teaching of both decimal concepts and computation with decimals has traditionally been delayed until the analagous topics with fractions have been considered. All too often this has meant that there has not been sufficient time available to do an adequate treatment of decimals because the fraction work has consumed so much time. Such a situation is doubly unfortunate now, since with Canada having adopted the metric system of measurement, there will be an increasing use of decimal notation and computation accompanied by a decreasing need for fractions.

There were five items dealing with computation with decimals on the Grade 12 test. The results obtained are summarized in Table 5-12.

Table 5-12
Grade 12 Results (N = 23 136)
Objective: Computation with Decimals (mean = 80.2%)

Item No.	Operation	Percent Correct	Panel Judgment
1	Subtraction	87	Satisfactory
5	Multiplication	78	Marginally Satisfactory
15	Addition	84	Satisfactory
17	Subtraction	86	Satisfactory
28	Division	66	Marginally Satisfactory

The Interpretation Panel felt that these results were weaker than the results for computation with fractions. In particular, they recommended that increased attention be paid to multiplication and division of decimals as well as to place value concepts.

The two items, 5 and 28, which resulted in marginally satisfactory performances by the students, are shown in Figure 5-1.

5. Multiply: .15 x .45 =

	Percent
A) 6.75	11
B) 0.0675	78 *
C) 0.675	8
D) 67.5	1
E) I don't know	1
No Response	1

28. Divide: $.12\overline{)\,.036}$

	Percent
A) 3	5
B) 0.003	13
C) 0.3	66
D) 0.03	13
E) I don't know	2
No Response	1

Figure 5-1: Grade 12 - Items 5 and 28

* the correct response is underlined

For each item above, the same non-zero digits are used in each distractor so that the questions involve proper placing of the decimal point in the answer more than they do ability to use the multiplication or the division algorithms. In light of this fact, the students' performance on these two items would certainly appear to be less than satisfactory.

5.3.3 Knowledge of Notation and Terminology

Table 5-13
Grade 12 Results (N = 23 136)
Ojective: Knowledge of Notation and Terminology (mean = 75.7%)

Item No.	Topic	Percent Correct	Panel Judgment
3	Square Root	87	Very Satisfactory
7	Factor	86	Strength
9	Powers of 10	75	Satisfactory
10	Scientific Notation	67	Satisfactory
20	Centimetres	69	Marginally Satisfactory
30	Exponents	87	Very Satisfactory
34	G.C.F.	78	Very Satisfactory
39	Obtuse Angle	62	Marginally Satisfactory
40	Diameter	78	Satisfactory
42	Solids	89	Very Satisfactory
44	Reciprocal	90	Strength
45	Primes	65	Satisfactory
51	Coordinates	72	Satisfactory
62	Roots	60	Satisfactory

The Interpretation Panel felt that there was a general weakness in the area of geometry, and that geometry should receive greater emphasis in the future. They felt that, particularly for academic students, the geometry should be deductive and not merely intuitive. Items 7 and 44 were particularly well done.

For Item 9, students were asked to simplify 10^4 and almost 20% chose 100 000 rather than 10 000 as their answer. On the other hand, on Item 30 which asked students to simply 4^3 performance was considerably better. It would appear that students may have been taught a rule for evaluating powers of ten (10^n is 1 followed by n zeroes), but have not remembered the rule correctly. This same item appeared on the Grade 8 test, where 12% chose 100 000 as the answer.

The results on Item 20, which is shown below, are surprisingly low, given the level of difficulty of the question.

20. 5 metres is the same length as:

		Percent
A)	50 centimetres	15
B)	500 centimetres	63
C)	50 millimetres	4
D)	500 millimetres	4
E)	I don't know	13
	No Response	1

Figure 5-2: Grade 12 - Item 20

Inability to obtain the correct answer to Item 20 would seem to indicate an almost total lack of familiarity with the basic relationships among the metric units of length; in this case, the students seem unable to make use of the fact that one metre is the same length as 100 centimetres. This low performance is particularly serious at the Grade 12 level since many of these students are in the final year of formal education. In the metric world in which they will be adults, familiarity with the metric units of length will be an important assest.

5.3.4 Knowledge of Other Algorithms

In addition to the four basic operations on whole numbers, fractions, and decimals, students are taught algorithms for performing a wide variety of mathematical operations. Some of these operations are reducing fractions to lowest terms, simplifying improper fractions, changing decimals to percents to fractions and vice versa, operations with integers, and simplifying expressions containing exponents.

Seven items on the Grade 12 test were used to sample students' abilities to employ such algorithms. The results obtained are shown in Table 5-14.

Table 5-14
Grade 12 Results (N = 23 136)
Objective: Knowledge of Other Algorithms (mean = 72.7%)

Item No.	Topic	Percent Correct	Panel Judgment
4	Integers	81	Very Satisfactory
8	Integers	66	Satisfactory
13	Percent	79	Satisfactory
16	Exponents	59	Satisfactory
31	Decimal	67	Marginally Satisfactory
35	Decimal	65	Marginally Satisfactory
46	Lowest Terms	92	Strength

Items 13 and 35, which are shown below in Figures 5-3 and 5-4, concern writing a fraction as a percent and a percent as a decimal. As the Interpretation Panel commented, skills tested here are basic knowledge of importance to everyone. The performance in this area needs improvement.

13. Written as a percent, $\frac{1}{5} =$

	Percent
A) 5%	7
B) 0.5%	12
C) 20%	79
D) 50%	1
E) I don't know	1
No response	1

Figure 5-3: Grade 12 - Item 13

35. Written as a decimal, 20% =

	Percent
A) 0.2	65
B) 0.02	10
C) 2.0	4
D) 20.0	18
E) I don't know	1

Figure 5-4: Grade 12 - Item 35

Item 31, also rated as marginally satisfactory, required students to express 1/8 as a decimal. Almost 20% of the students selected 0.8 as their response, simply placing the denominator of the fraction after the decimal point. The performance on Items 8 and 16 were rated satisfactory despite the relatively low percent correct on each because the content of these items was judged to be less essential to all students. Item 8 asked students to find the difference of two integers (-5) - (-9), while in Item 16 students were asked to apply laws of exponents in order to simplify $3^5 \times 3^2$. It will come as no surprise to teachers of mathematics that 24% chose 9^7 as their response to the latter item.

5.4 Test Results: Comprehension Domain

Four objectives made up the Comprehension Domain. These objectives dealt with the comprehension of number concepts, of measurement concepts, of geometric concepts, and of algebraic concepts. Comprehension, as a cognitive behaviour, is higher than Computation and Knowledge. Comprehension, as it is used here, includes knowledge of concepts, principles, rules, and generalizations as well as the ability to transform problem elements from one mode to another and the ability to read and interpret problems.

5.4.1 Comprehension of Number Concepts

By the end of Grade 12, all students have been exposed to the field of rational numbers. They have studied the various forms in which rational numbers are written as well as methods of performing operations on such numbers. The test items utilized for this objective were designed to assess students' grasp of a selected number of important concepts, principles, and generalizations concerning rational numbers. The results obtained are summarized in Table 5-15.

Table 5-15
Grade 12 Results (N = 23 136)
Objective: Comprehension of Number Concepts (mean = 67.7%)

Item No.	Content	Percent Correct	Panel Judgment
12	Division with 0	62	Satisfactory
14	Order	86	Very Satisfactory
18	Fraction	51	Weakness
32	Square Root	73	Satisfactory
47	Order	59	Marginally Satisfactory
50	Rounding	75	Satisfactory

5.4.2 Comprehension of Measurement Concepts

The Grade 12 assessment instrument included five items dealing with comprehension of measurement concepts. Of these, one item, Item 43, dealt with measurement of angles and the remainder dealt with the metric system of measurement. The data concerning this objective are presented in Table 5-16.

Table 5-16
Grade 12 Results (N = 23 136)
Objective: Understanding of Measurement Concepts (mean = 78.8%)

Item No.	Content	Percent Correct	Panel Judgment
19	Temperature	87	Very Satisfactory
21	Capacity	90	Very Satisfactory
22	Mass	54	Weakness
23	Length	82	Very Satisfactory
43	Angle Measure	81	Satisfactory

On all five items, the students were asked to select the most reasonable measure from among four possibilities for a given situation. The Interpretation Panel expressed the opinion that the results obtained were satisfactory or better except for the performance on Item 22. They felt that this low performance was understandable for Grade 12 students at this time.

If one includes Item 20 which was discussed earlier along with Items 19, 21, 22, and 23, then a general indication of students' familiarity with the metric system can be obtained. The average for all five items is 75.3% with one result (Item 22) being rated as a weakness. Item 20 was marginally satisfactory, and the remaining three items were very satisfactory.

Overall the students seemed to be familiar with some of the basic metric concepts although the relationship between metres and centimetres as well as the use of the kilogram as the unit of mass are somewhat weak. It is important that steps be taken to ensure that all students become familiar with the metric system of measurement before they leave school.

Recommendation 5-4: Schools and school districts should implement programs to familiarize all of their students, but especially those at the senior secondary level, with the basic concepts and principles of the metric system of measurement.

5.4.3 Comprehension of Geometric Concepts

Table 5-17 contains a summary of the information concerning the four items used to assess students' understanding of geometric concepts.

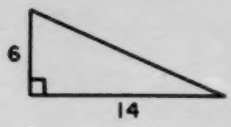
Table 5-17
Grade 12 Results (N = 23 136)
Objective: Comprehension of Geometric Concepts (mean = 57%)

Item No.	Content	Percent Correct	Panel Judgment
38	Equilateral Triangles	75	Very Satisfactory
41	Congruence	17	--
52	Area	55	Marginally Satisfactory
54	Volume	81	Very Satisfactory

The Interpretation Panel felt that the overall performance on these items was satisfactory or better. They attributed the students' poor performance on Item 41 to the nature of the item itself, and felt that the result did not truly reflect students' understanding of congruent triangles. For that reason, no Panel Judgment has been listed for Item 41.

The results of Item 52 deserve some attention. On this item, as is shown in Figure 5-5, over one-quarter of the students determined the area of the triangle by simply finding the product of the base and the altitude. Another ten percent said they did not know how to find the area.

52. Find the area of this right triangle:



		Percent
A)	42	55
B)	20	5
C)	84	26
D)	21	3
E)	I don't know	10
	No Response	1%

Figure 5-5: Grade 12 - Item 52

The formula for finding the area of a triangle is one of the most basic area formulas, and is one which is taught to all students at several grade levels. The fact that almost half the Grade 12 students could not do this item correctly must be interpreted as a less than satisfactory performance and, perhaps, as a weakness.

The Panel's comments to the effect that Item 41 is a poor item and does not relate to the objective should be accepted with a degree of caution. The item, shown in Figure 5-6, requires students to select two triangles that ARE congruent, not triangles that appear to be conguent.

41. Which two triangles are congruent?

		Percent
A)	I and IV	17
B)	II and III	3
C)	I and III	65
D)	II and IV	4
E)	I don't know	10

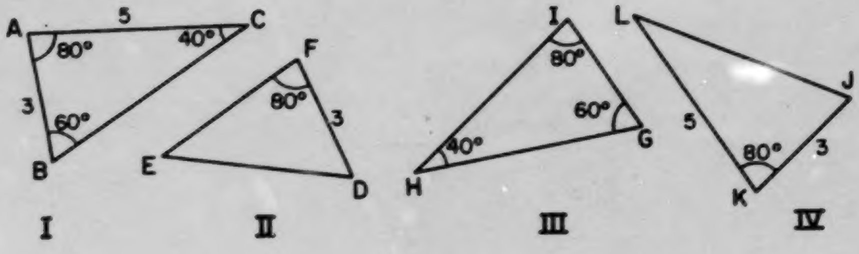


Figure 5-6: Grade 12 - Item 41

Sixty-five percent of the students chose the triangles which are equiangular and therefore similar, I and III, but not necessarily congruent. Such students may have looked for triangles which appeared to be congruent rather than using their knowledge of congruence conditions to answer the question. On the other hand, if students did reason in that way, then why did they not choose I and IV, which was the first distractor and where the triangles certainly appear to be congruent since indeed they are? Although it is impossible to be certain, a reasonable explanation of the students' selection of distractor C is that they erroneously concluded that if two triangles are equiangular, then they are congruent. In this light, the performance on Item 41 may be seen to indicate a weakness.

5.4.4 Comprehension of Algebraic Concepts

Few of what most people would consider as algebraic concepts are among the essential skills and concepts of mathematics that one needs to lead a full and happy life. However, all of the items listed in Table 5-18 measure mastery of fundamental principles, rules, and the ability to apply formulas to which all students are exposed before the end of Grade 10. Thus, through it may be true that all of these concepts are not essential in everyday life, it is true that some of them are essential in mathematics.

Table 5-18
Grade 12 Results (N = 23 136)
Objective: Comprehension of Algebraic Concepts (mean = 63.9%)

Item No.	Content	Percent Correct	Panel Judgment
48	Order of Operations	67	Satisfactory
55	Slope	43	Marginally Satisfactory
56	Evaluate Expressions	83	Very Satisfactory
57	Linear Equation	82	Very Satisfactory
61	Factoring	61	Satisfactory
63	Simultaneous Equations	63	Very Satisfactory
64	Simplify Expressions	44	Marginally Satisfactory
67	Write an equation	70	Very Satisfactory
68	Apply Formula	62	Marginally Satisfactory

In the opinion of the Interpretation Panel, the results for this objective were very satisfactory. The areas which were judged weakest, finding the slope of a line and removing parentheses to simplify a linear expression, they felt to be only marginally useful to non-academic students. They suggested that the low result on Item 68 (Figure 5-7) might indicate a need to deal more adequately with the topic of interest, and perhaps especially for academic students.

The formula to calculate simple interest is $I = Prt$ where I is the interest, P is the principal, r is the rate, and t is the time in years.

68. Find the *interest* on a principal of $1000 invested for two years at an annual rate of 7%.

		Percent
A)	$ 140	62
B)	$1400	12
C)	$ 70	12
D)	$ 14	6
E)	I don't know	7
	No Response	2

Figure 5-7: Grade 12 - Item 68

For Item 68, students were given the simple interest formula and asked to calculate an amount of interest due. The behaviours involved are not unlike those involved in finding the area of a triangle, (Item 52) except that in this case the formula is provided.

Almost 40% of the students were unable to do this exercise and 12% gave the completely unreasonable response of $1400 as being the interest due on a principle of $1000 after two years at a rate of 7%. The fact that so many students cannot calculate simple interest, given the formula, should be a cause of some concern to mathematics educators. In point of fact, an examination of all of the items on the test which deal with percent and applications of percent leaves one with the impression that this is a general area of less than satisfactory performance.

Recommendation 5-5: Curriculum Development Branch should examine the situation with regard to the teaching of percent and its applications, and give specific suggestions to teachers regarding appropriate materials and methods to be used in teaching these topics.

5.5 Test Results: Applications Domain

Included under the Applications domain are the abilities to solve routine problems, analyze data, and recognize patterns. Eighteen items, grouped under three objectives, were used to assess student learnings in this domain.

5.5.1 Solve Problems Involving Operations with Whole Numbers, Fractions, Decimals, and Percent

In a sense, almost all problems in mathematics involve operations with whole numbers, fractions, decimals, and percents; however, the intention is to include here those problems which involve such operations and nothing more. In that sense, such arithmetic problems are distinct from geometric or algebraic problems.

The test included nine arithmetic problems, and the results obtained by the students on these items are presented in Table 5-19.

Table 5-19
Grade 12 Results (N = 23 136)
Objective: Solves Arithmetic Problems (mean = 74.8%)

Item No.	Topic	Percent Correct	Panel Judgment
24	Unit Pricing	65	Marginally Satisfactory
25	Credit Buying	70	Satisfactory
26	Average	89	Very Satisfactory
27	Discount	86	Very Satisfactory
58	Percent	87	Satisfactory
59	Percent	79	Satisfactory
60	Percent	66	Marginally Satisfactory
71	Commission	62	Marginally Satisfactory
72	Tax Table	69	Marginally Satisfactory

The Interpretation Panel felt that there was room for improvement of students' performance on these types of problems. They wondered if sufficient time is being spent on the teaching of problem-solving and suggested that the performance would improve if students studied more business and consumer mathematics topics. Finally, they hypothesized that students' performance might reflect inadequate training in persistence, care, and attention to detail.

The Panel's last comment is an important one. There is no doubt that persistence, care, and attention to detail are necessary but not sufficient conditions to good problem-solving. Teachers have similarly decried students' seeming carelessness and inattention to detail for generations. It may be, however, that students will improve their skills in this area if teachers succeed in bringing a little of the real world into the mathematics classroom, thereby enlivening their discussions of topics which might otherwise be seen by the students as irrelevant and hence undeserving of persistence, care and attention to detail.

As the Panel has suggested, students' performance might improve if more consumer and business mathematics topics were taught, especially at the senior secondary level where they are most likely to be meaningful to the students. On the Assessment test, the few items ranked as marginally satisfactory are all consumer items, as are two rated very satisfactory and one rated satisfactory.

Special note should be made of Item 72 in which students were shown a page from the Canada Income Tax Guide and asked to find the total amount of tax due on a specified Taxable Income. Just over 30% of the respondents obtained the incorrect answer thereby giving some evidence of their inability to read a table correctly, a table which many of them must have already used and which all of them will use sooner or later.

Recommendation 5-6: Teachers and teacher educators should stress the overriding importance of problem-solving in mathematics and they should attempt to teach their students various strategies to employ in attempting to solve problems in mathematics.

Recommendation 5-7: Individual teachers and mathematics departments should set up their own collections of problems and activities out of which problems grow, keeping in mind the interests of their students, and making use of local information in order that the problems will be more interesting to students.

Recommendation 5-8: The Curriculum Development Branch should give immediate and serious consideration to ways and means of ensuring that all students completing Grade 12 have been taught the major topics of consumer mathematics.

5.5.2 Solve Problems Involving Geometry and Measurement

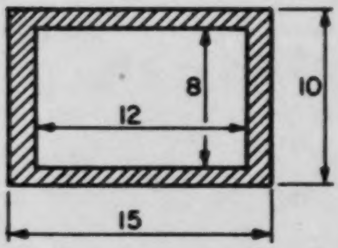
Seven items were utilized to assess students' abilities to solve geometric and measurement problems. The item results are displayed in Table 5-20.

Table 5-20
Grade 12 Results (N = 23 136)
Objective: Solve Problems Involving Geometry and Measurement (mean = 55%)

Item No.	Topic	Percent Correct	Panel Judgment
33	Area	35	Weakness
36	Scale Drawing	81	Very Satisfactory
37	Area	54	Weakness
49	Surface Area	37	Weakness
53	Area of Circle	72	Very Satisfactory
65	Similarity	63	Satisfactory
66	Theorem of Pythagoras	43	Weakness

The results of this objective are poorer than for any of the others. The Panel rated four of the item results as indicating weakness. In the Panel's opinion, students may have done poorly on Item 49 because they either did not understand the term "surface area" or else failed to read carefully enough. The results show that 33% of the respondents found the volume rather than the surface area for Item 49. The Panel also reiterated its previous point to the effect that the students' poor performance may reflect inadequate training in persistence, care, and attention to detail.

Student performance was very satisfactory on an item involving scale drawing, Item 36, and on Item 53 which dealt with the relative areas of two related circles. Actually the performance on Item 53 was surprisingly good when it is compared to that on Items 33, 37, 49, and 66.



37. What is the area of the shaded portion of this figure?

		Percent
A)	54 *	54
B)	96	16
C)	120	6
D)	60	8
E)	I don't know	15
	No Response	1

Figure 5-8: Grade 12 - Item 37

This is a relatively straightforward problem requiring two applications of the formula for the area of a rectangle and then finding the difference between these areas; yet, almost half the students were unable to solve it. Fifteen percent responded "I don't know" and an almost equal number simply found the area of the inner rectangle.

The general impression left by these results is that students are leaving school with an inadequate grasp of geometry. In recent years, the emphasis on geometry in the secondary school curriculum has greatly lessened. Perhaps we are now seeing, for the first time, the results of this de-emphasis.

Recommendation 5-9: Curriculum Development Branch should reconsider the nature and scope of the geometry curriculum at the secondary school level, keeping in mind the results obtained by the students on the geometry items on this test.

5.5.3 Solves Algebraic Problems

Only two items relevant to this objective were placed on the Grade 12 test. As a result, the Interpretation Panel found it impossible to make an overall comment on the objective. The individual item judgments are shown in Table 5-21.

Table 5-21
Grade 12 Results (N = 23 136)
Objective: Solving Algebraic Problems (mean = 57.5%)

Item No.	Topic	Percent Correct	Panel Judgment
69	Use Formulas	48	Weakness
70	Interpret Graphs	67	Satisfactory

On Item 70, 67% of the students were able to read a graph of speed versus braking distance correctly. Although the Panel rated this performace as satisfactory, a much higher result would have been preferred, particularly in light of the ever more extensive use of graphs as a means of summarizing and presenting data.

Item 69 was a companion to Item 68 (see Figure 5-7). For this item, students were given the interest, rate, and time involved and asked to find the principal amount. In order to do this, they had to perform an algebraic manipulation on the formula in order for it to read P = i/rt. As the results show, slightly less than half the students were able to obtain the correct answer. Sixteen percent responded "I don't know" and 17% said $720 was the answer. This latter result is obtained by simply multiplying all three numbers that are given in the problem without regard to their application in the formula.

The Interpretation Panel again repeated its comment to the effect that students' performance on these items may reflect inadequte training in persistence, care, and attention to detail.

5.6 Grade 12 Reporting Categories

Mathematics achievement is the end result of the coalescing of a great number of student-based factors, both intrinsic and extrinsic. Attributes inherent in the student, programmatic and curricular variables, as well as the effect of environmental variables such as teacher differences, all contribute in varying and largely unknown degree to a given student's overall performance. Of the fairly large number of such variables which the conventional wisdom, current educational practice, and the endeavors of educational researchers have identified as being related to mathematics achievement, a limited number were selected for scrutiny in the Mathematics Assessment (see Chapter 1, Section 1.4).

A great deal more information concerning the relationship between certain personal background variables and achievement on the Mathematics Assessment test was collected than could possibly be reported in this volume. A more complete rendering may be found in the Technical Report dealing with test results which is obtainable from the Learning Assessment Branch. Researchers or others who wish to have access to the original data in order to seek answers to their own questions on issues relevant to the Mathematics Assessment should also direct their requests to the Learning Assessment Branch.

In the sections that follow, all of the results reported and recommendations made are based upon correlational trends. No attempt is made to imply that cause and effect relationships exist since the Mathematics Assessment was not designed to identify such relationships.

It remains for studies designed as follow-ups to the present one to seek to identify such relationships. Thus, while the assessment results show several fairly strong relationships between a student's sex and that student's achievement in mathematics, this does not imply that achievement in mathematics is determined by a student's sex. All that can be said on the basis of the assessment data is that there appears to be a relationship between the two variables.

For each of the reporting categories discussed in succeeding sections, reference is made to the various domains, objectives, and items evaluated in the Mathematics Assessment. For ease of reference, a labelling system for domains and objectives has been adopted and will be used throughout the remainder of this chapter. Each objective has been assigned a code number consisting of two digits separated by a period. For example, Ojbective 2.2 refers to Domain 2 (Comprehension), Objective 2 (Understanding of Measurement Concepts). In Table 5-22, the rightmost column indicates the section of Chapter 5 where the Grade 12 population results for the appropriate objective were initially discussed.

Table 5-22
Grade 12: Code Numbers used for Objectives

Code No.	Objective	Location of Population Results
1.1	Computation with Fractions	Section 5.3.1
1.2	Computation with Decimals	" 5.3.2
1.3	Notation and Terminology	" 5.3.3
1.4	Other Algorithms	" 5.3.4
2.1	Number Concepts	" 5.4.1
2.2	Measurement Concepts	" 5.4.2
2.3	Geometric Concepts	" 5.4.3
2.4	Algebraic Concepts	" 5.4.4
3.1	Arithmetic Problems	" 5.5.1
3.2	Geometric and Measurement Problems	" 5.5.2
3.3	Algebraic Problems	" 5.5.3

5.6.1 Mathematics Background

The student population at any grade level is heterogeneous with respect to mathematics achievement, but at the senior secondary levels it is at its most diverse due to the additional factor of variability of student background in mathematics. Students at every level vary greatly with respect to their aptitude, interest, and ability in mathematics; but, at the senior secondary level they also vary in the amount of mathematics to which they have been exposed. Some have taken no mathematics courses since the end of the last compulsory course in Grade 10; at the opposite extreme, others are enrolled in honours sections of Math 12.

It is entirely predictable that students with more background in mathematics will perform better on a mathematics test that will students who have less. In that sense the results reported here are not that extraordinary. On the other hand, it should be remembered that the basic goal of the Mathematics Assessment was to obtain a measure of all students' mastery of certain essential skills and concepts of mathematics. From this point of view it is important to see how each subgroup of the population performed as well as to examine the achievement of the population as a whole.

A comparison of students' performance on the Mathematics Assessment test as a function of their mathematics backgrounds is displayed graphically in Figure 5-9. Students taking or having completed Mathematics 12 are designated as Math 12; students taking or having completed some form of Mathematics 11 as their last mathematics course, as Math 11; and students completing Mathematics 10 as their highest mathematics course, as Math 10.

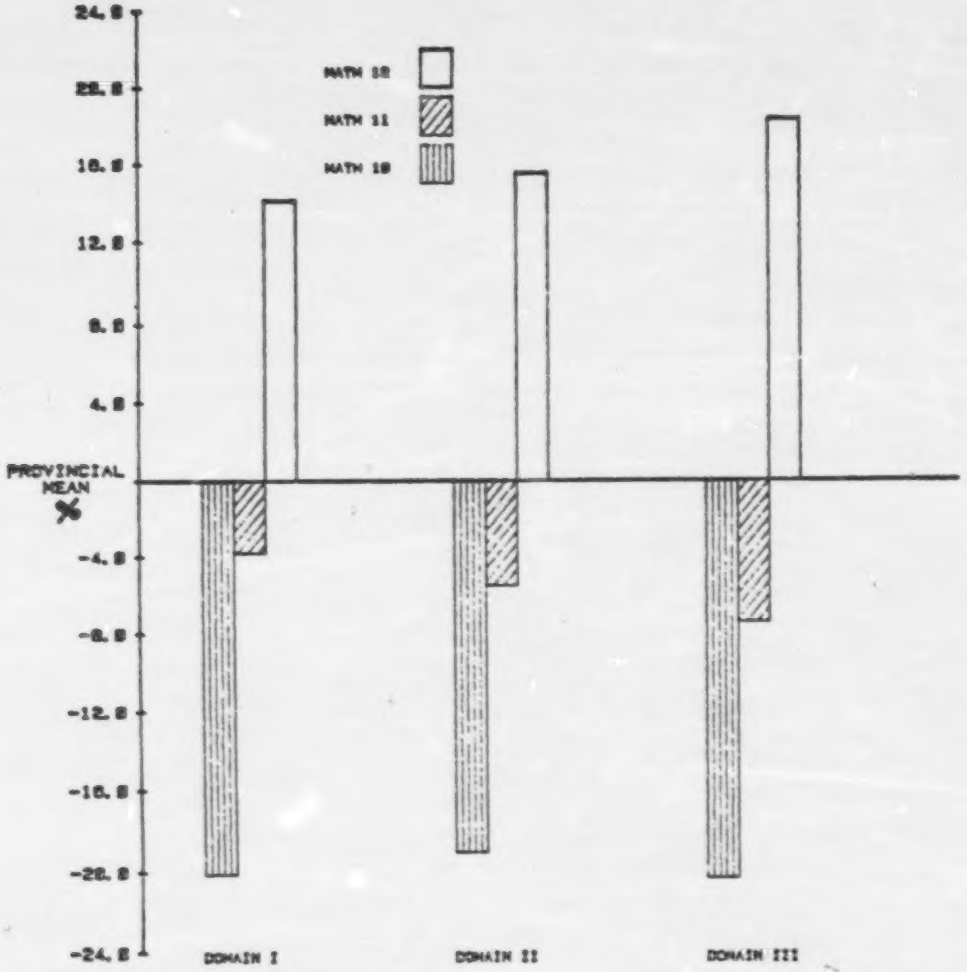


Figure 5-9: Grade 12 Results by Mathematics Background

The Math 10 group's performance is lowest on each objective and, in some cases, it is markedly so. As will be seen in Chapter 6, this group scored lower than the Grade 8 group on many of the items which were common to the two instruments. On the positive side, the three objectives where the Math 10 group's performance was closest to that of the Math 12 group were solution of arithmetic problems, comprehension of measurement concepts, and computation with decimals; all three being areas of practical importance and application.

That something must be done to improve the mathematical competencies of the Math 10 group seems abundantly clear from the results, especially when one examines the individual item results obtained by this group. Of the 3 506 students in the Math 10 group:

1) 49% were able to interpret an income tax table (Item 72)
2) 49% were able to select the best purchase (Item 24)
3) 45% were able to read information from a graph (Item 70)
4) 44% obtained the correct quotient for $.12\overline{).036}$ (Item 28)
5) 42% correctly wrote 1/8 as a decimal (Item 31)
6) 42% correctly calculated an amount of simple interest given the formula (Item 68)
7) 39% correctly wrote 20% as a decimal (Item 35)
8) 26% were able to calculate the principal, given the amount of interest, the rate, the time, and the formula $i = Prt$ (Item 69), and
9) 24% were able to find the area of a right triangle (Item 52).

Both the Math 12 and the Math 11 groups performed satisfactorily on the whole. As was to be expected, the averages decrease from one domain to the next. The highest performance was achieved in Computation and Knowledge; the lowest, in Applications.

The graph displayed in Figure 5-10 presents a comparison of student performance on each objective for each of four age groupings: 19 and over (N = 1 389), 18 year olds (N = 7 127), 17 year olds (N = 13 993), and 16 or younger (N = 477). On each objective the performance decreases with an increase in age.

Similar differences are found in most cases when mathematics background is taken into account along with age. Among both the Math 12 and Math 11 groups, the younger students do better than their older counterparts. In the Math 10 group (N = 3 506), on the other hand, the handful of students who are sixteen or less (N = 46) do less well than the seventeen year olds on virtually every objective.

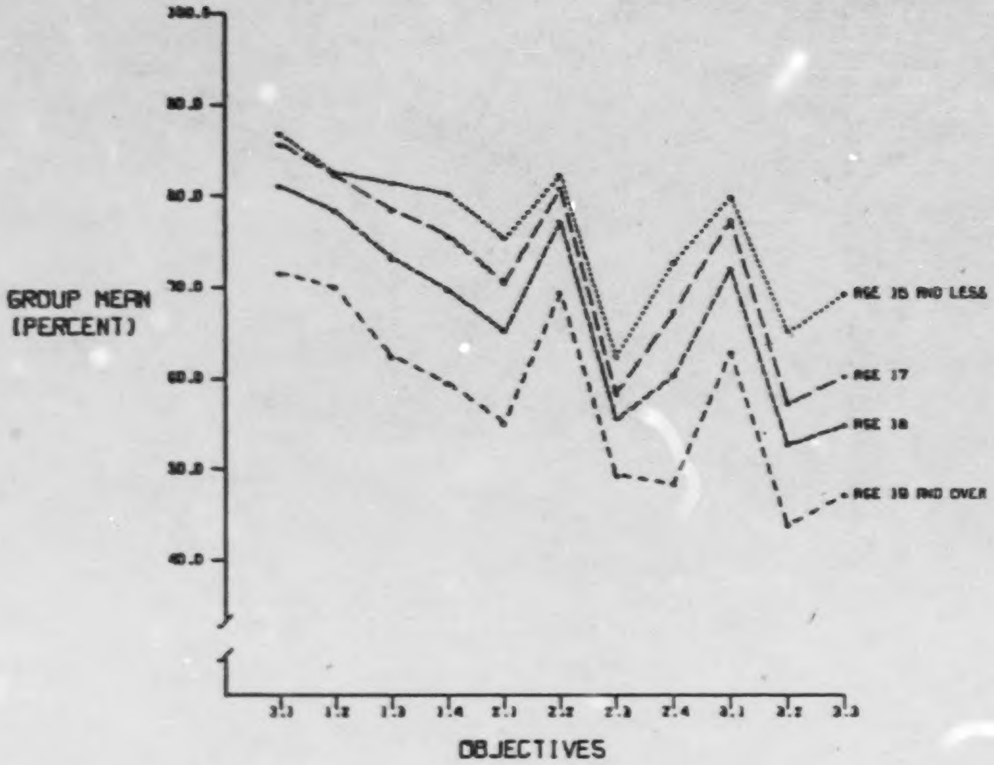


Figure 5-10: Grade 12 Results by Age

5.6.3 Sex Differences

As has been reported in other studies such as the National Longitudinal Study of Mathematics Ability (NLSMA) and the National Assessment of Educational Progress (NAEP), the data displayed in Figure 5-11 show a definite trend to superior achievement by males in the Mathematics Assessment. Both NLSMA and NAEP reported that girls outperformed boys only in those areas of mathematics such as computational skills which involve lower level cognitive behaviours. Similar results were found in this assessment.

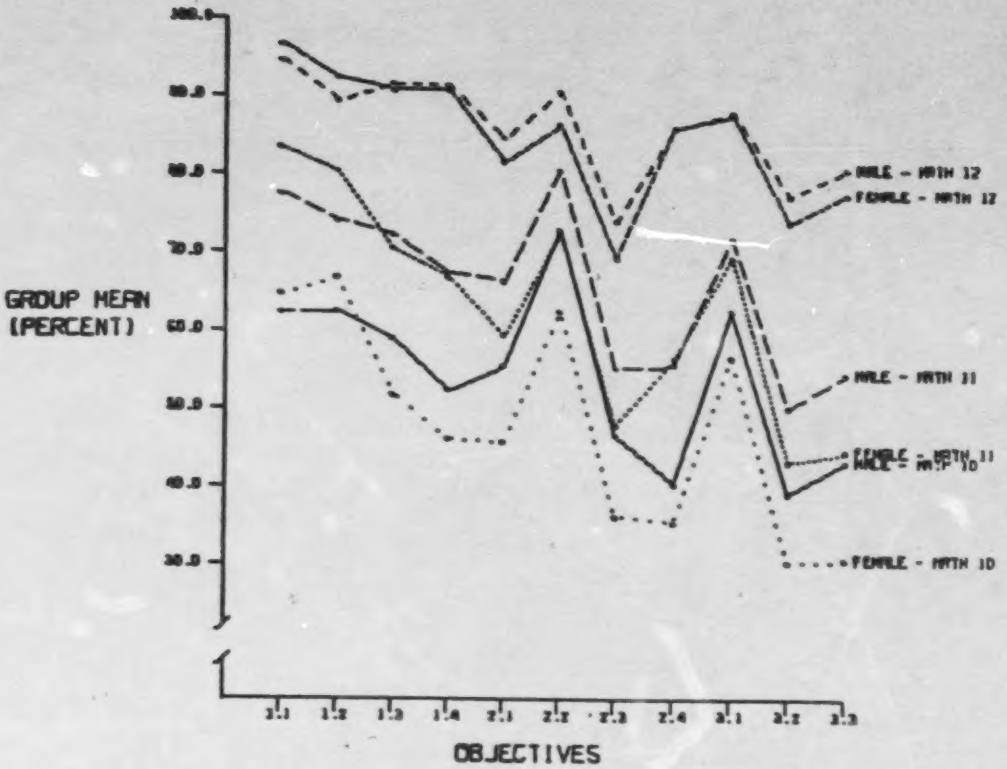


Figure 5-11: Grade 12 Results by Sex

Analysis of these data by mathematics background leads to the same result. The differences between achievement of males and females are relatively small among the Math 12 group but they are, with one exception, in the same direction as for the total group. The differences are greater among the Math 11 group, and even more pronounced among the Math 10 group.

5.6.4 Number of Schools Attended

There was a remarkable consistency of results when they were examined in the light of the number of schools attended by students. For example, there was a total variation of only 0.8% on objective 1.1 among students who had attended between one and seven schools. On the other hand, those 1 856 students who had attended eight or more schools averaged three percent less on the same objective.

The same pattern applied to each objective. Having attended a large number of schools, eight or more was consistently related to lower performance; otherwise the number of schools attended seemed to be unrelated to mathematics achievement at the Grade 12 level.

5.6.5 Use of Hand-Held Calculators

Three graphs charting the assessment results by aspects of calculator use are displayed in Figures 5-12 through 5-14. For each objective and for each type of calculator use, the group of students who use hand-held calculators out-perform the non-calculator group. This is true even for such non-computational objectives as Knowledge of Notation and Terminology (1.3), Comprehension of Measurement Concepts (2.2) and Comprehension of Geometric Concepts (2.3).

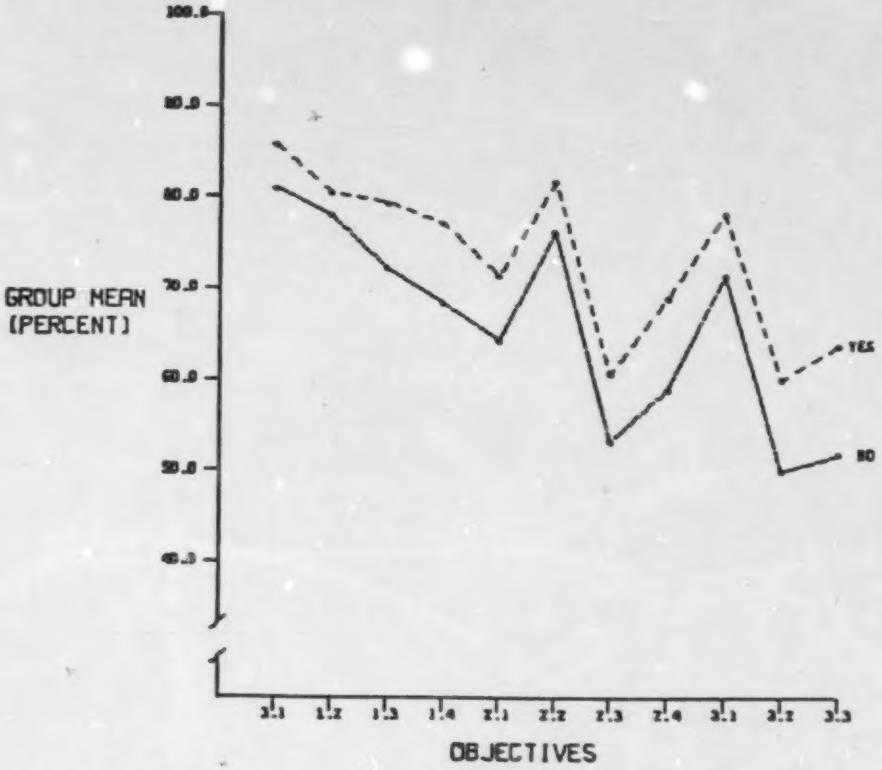


Figure 5-12: Grade 12 Results by Use of Calculators at Home

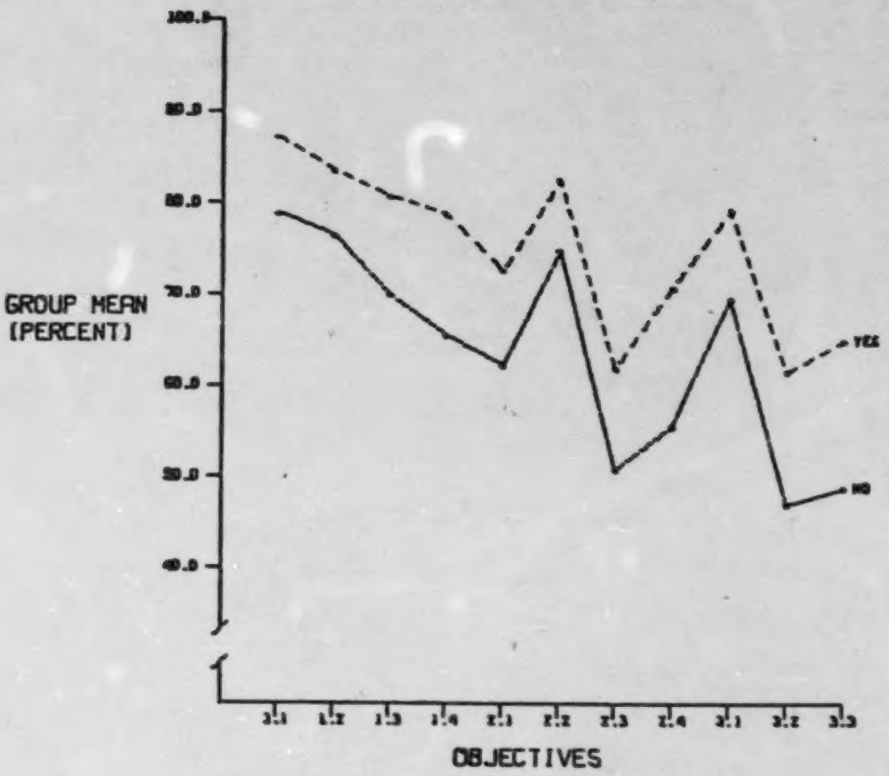


Figure 5-13: Grade 12 Results by Use of Calculator for Homework

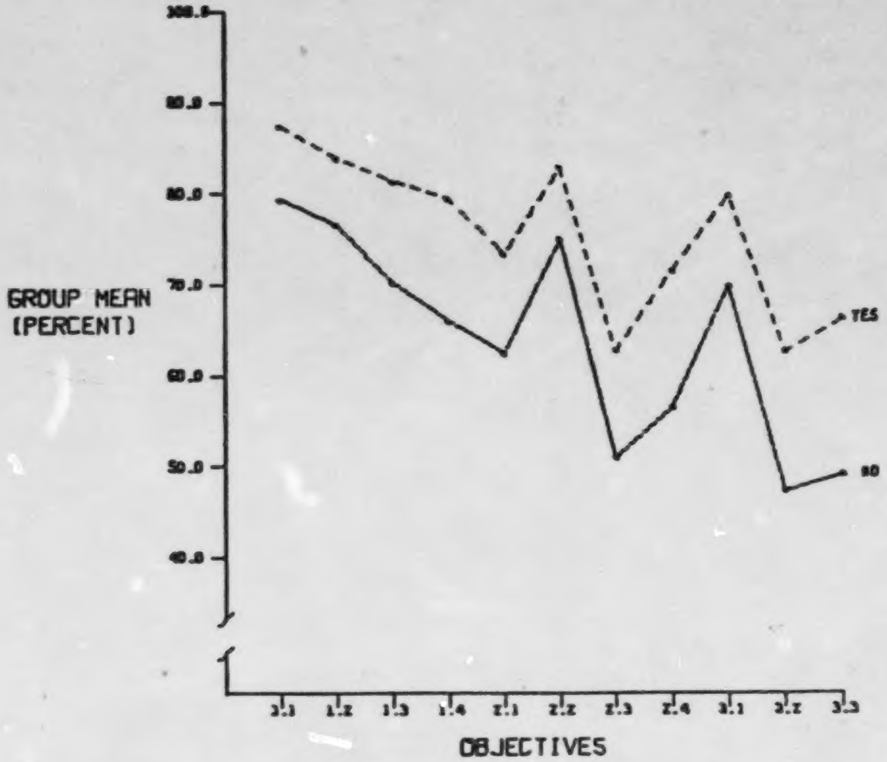


Figure 5-14: Grade 12 Results by Use of Calculator in School

It seems logical to conclude that these differences are caused by some confounding of the mathematics background variable with the calculator group. However, similar results are obtained when the calculator questions are analyzed for the Math 12, 11 and 10 groups separately. The difference between the calculator and non-calculator groups are more pronounced among the Math 10 group than among the Math 11 or the Math 12 groups, but they are in the same direction for all three groups on virtually every objective.

5.6.6 Time Spent on Assignments

The question concerning the amount of out-of-class time students spent on mathematics assignments was directed only to those students who were taking a mathematics course at the time of the Mathematics Assessment. Of the 23 136 students who wrote the test, 11 522 or 49.8% indicated that they were not taking a mathematics course. A breakdown of the data on time spent on assignment is shown in Table 5-23.

Table 5-23
Grade 12 Results: Time Spent on Assignments per Day (Percent)

Time Spent	All Students	Math 12	Math 11	Math 10
None	14.4	6.8	21.5	40.3
Less than 30 Minutes	36.6	41.5	32.6	19.0
More than 30 Minutes	37.4	47.6	25.1	12.0
No Response	9.9	2.6	18.6	26.5
Multiple Response	1.8	1.5	2.2	2.1

The "all students" colum in Table 5-23 is not a linear combination of the other three columns. The algorithm used to place students in the Math 10, 11, and 12 groups was based upon students' responses to two items, one dealing with courses presently being taken and the other with the last course successfully completed. Because of this, some students could not be uniquely classified into one of the three mathematics background categories.

The results of comparing amount of time spent on homework with achievement on the eleven assessment objectives are summarized in Table 5-24. As in the case of the calculator data, the differences on any one objective are not usually very great. It is the consistency of the trends which are evident in the Math 12 and Math 11 groups which are of most interest.

Table 5-24

Grade 12 Results by Time Spent on Homework
Number of Objectives on Which Homework Groups Attained Highest Score

	Time Spent on Homework:		
	None	Less than 30 Min/Day	More than 30 Min/Day
All Students*	0	7	5
Math 12	0	11	0
Math 11	0	10	1
Math 10*	0	7	5

* includes 1 tie

As is shown in the table, the no-homework group never attained the highest group score on an objective. In point of fact, this group was always last and usually by a considerable margin. Among the Math 11 and 12 groups, there is a definite trend for the group that spends less than thirty minutes a day on mathematics assignments to achieve better results than either of the other two groups.

5.6.7 Parental Education Level

NAEP found that parental education level was strongly related to student performance. Students whose parents had no secondary school education scored between eight and thirteen percent below the national average, while those students who had at least one parent who had had some post-secondary education were six to seven percent above the national mean. These results were particularly apparent among the seventeen year olds examined by NAEP, the group closest in age to the B.C. Grade 12 population.

The results displayed in Figures 5-15 and 5-16 parallel the NAEP findings regarding the relationship between student achievement and parental education level, although the mean differences are considerably smaller than those found by NAEP.

The results show a positive relationship between student achievement and the highest education level achieved by both parents considered individually. It is interesting to note that, in both cases, the lowest performance was recorded by those students whose father or mother had completed junior secondary school.

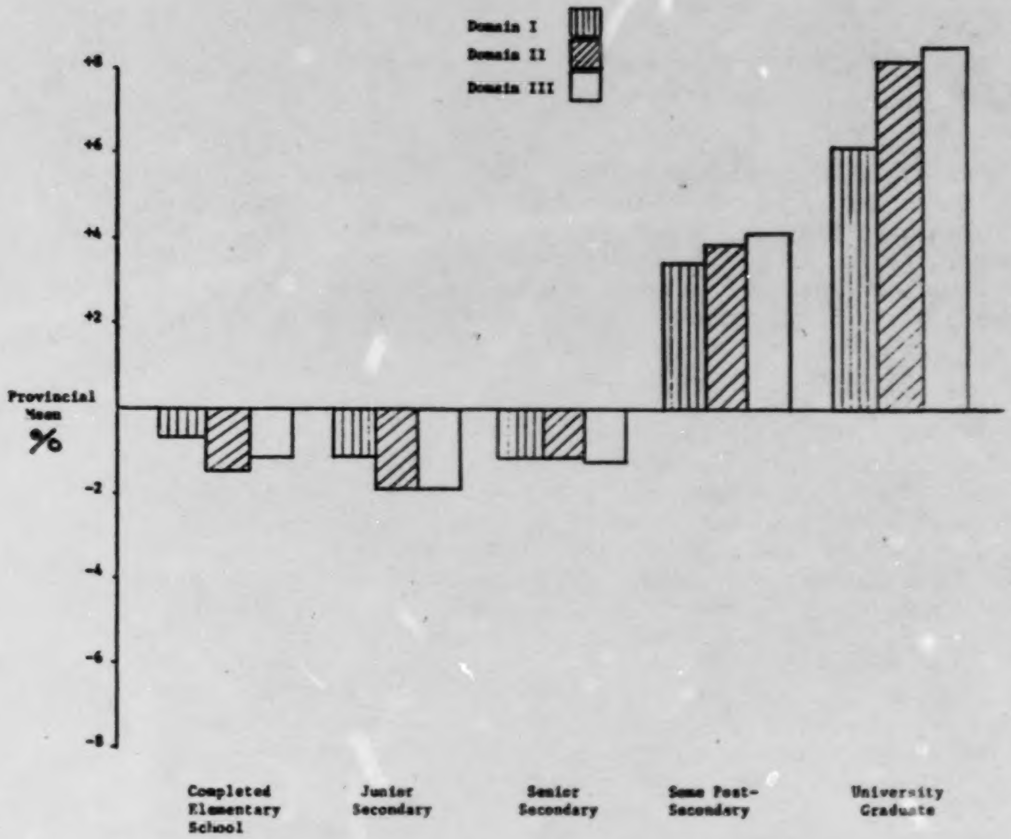


Figure 5-15: Mean Differences from Provincial Performance Levels by Father's Education Level

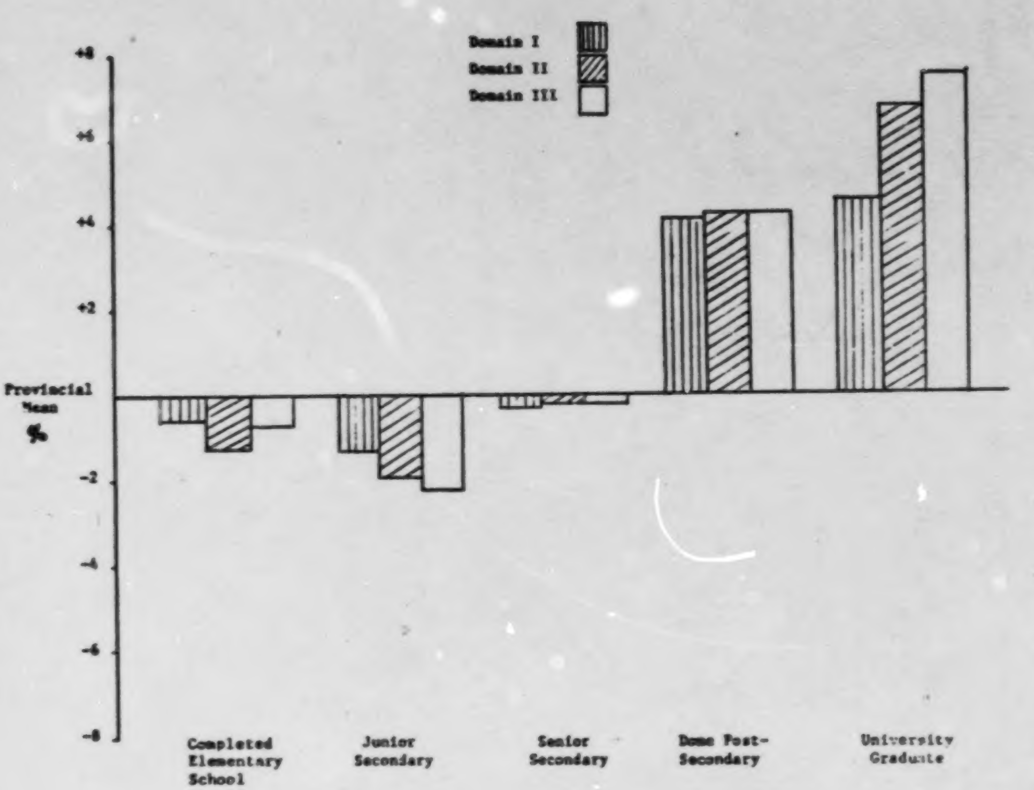


Figure 5-16: Mean Differences from Provincial Performance Levels by Mother's Education Level

5.6.8 Future Plans

In Figure 5-17, the results of the assessment are reported in terms of students' future plans. For each Domain, the group planning to attend university exceeded the provincial mean for that Domain by the greatest amount: about 11% for Domain 1, 13% for Domain 2, and 15% for Domain 3. The poorest performance on each Domain was recorded by those students who indicated they would seek full-time employment upon completion of secondary school.

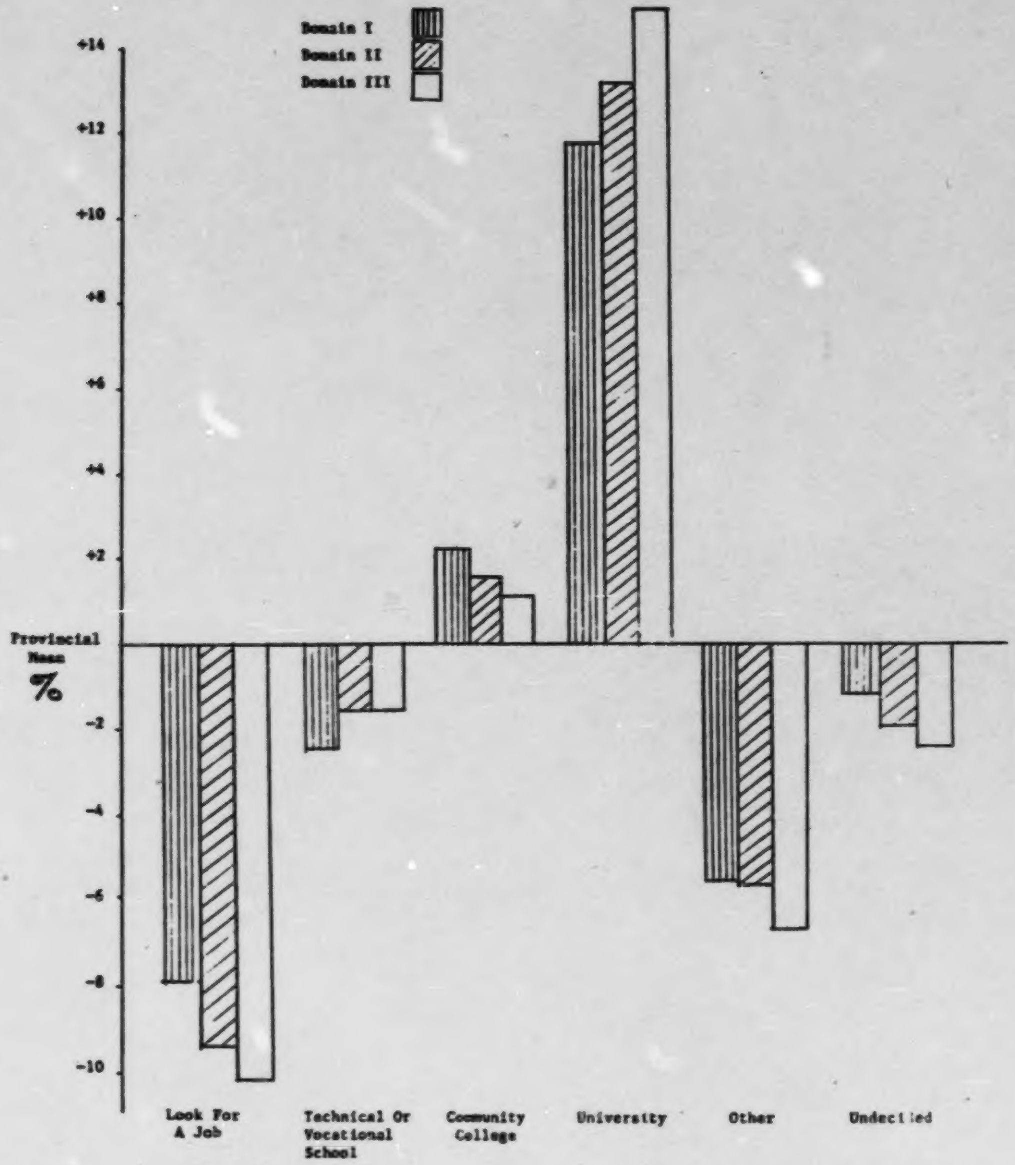


Figure 5-17: Mean Differences from Provincial Performance Levels by Future Plans

5.7 Reporting Categories from the Reading Assessment

In addition to the mathematics test, an assessment test in Reading was given at the Grade 12 level. These tests contained similar, and in some cases, identical background information questions. On both the Mathematics and Reading tests, students were asked their birthdate, sex, and number of schools attended. Using common information, a computer search was able to match the complete reading and mathematics data for sixty-three percent of the Grade 12 students. A data file was created to contain the information and results on both tests for the matched students so that comparisons between their performance on the two tests could be made.

The new data file was used to obtain further information on student performance and to correlate certain aspects of student performance in mathematics with student performance in reading. In Section 5.6 of this report, the data of the Mathematics Assessment were organized according to certain reporting categories such as age, sex, and use of hand-held calculators. In this section, the Mathematics Assessment data are organized by two reporting categories obtained from the Reading Assessment.

Domain Two of the Reading Assessment was Comprehension as it was in the Mathematics Assessment. Correlations were computed on the Grade 12 Mathematics Assessment results for the four objectives of the Comprehension Domain and the three objectives of the Applications Domain with the Reading Assessment results for the two objectives of their Comprehension Domain.

5.7.1 Reading Reporting Categories

The two reporting categories from the Grade 12 Reading Assessment which are presented in this section concern language spoken and television watching. The three items shown in Figure 5-19 appeared on the Grade 12 Reading test.

1. Were you born in Canada?

   Yes .... ☐
   No .... ☐

2. Did you usually speak a language other than English before you started in Grade 1?

   Yes .... ☐
   No .... ☐

3. Is English the language spoken in your home?

   Yes .... ☐
   No .... ☐

Figure 5-18: Place of Birth and Language Items from the Grade 12 Assessment

The results for the three items were used to organize the grade/year 12 students into five groups. The groups were defined as follows:

1. Non-Canadian, Non-English -- All grade/year 12 students who responded "No" to item 1, "Yes" to item 2, and "No" to item 3 in Figure 5-18.

2. Canadian, Non-English -- All grade/year 12 students who responded "Yes" to item 1, "Yes" to item 2, and "No" to item 3 in Figure 5-18.

3. First Generation Canadian -- All grade/year 12 students who responded "Yes" to item 1, "No" to item 2, and "No" to item 3 in Figure 5-18.

4. Non-Canadian, English -- All grade/year 12 students who responded "No" to item 1, "No" to item 2, and "Yes" to item 3 in Figure 5-18.

5. Canadian, English -- All grade/year 12 students who responded "Yes" to item 1, "No" to item 2, and "Yes" to item 3 in Figure 5-18.

Once the data were organized into the five groups, the results on each of the eleven objectives for the Grade/year 12 Mathematics Assessment were computed. These are presented in Figure 5-19.

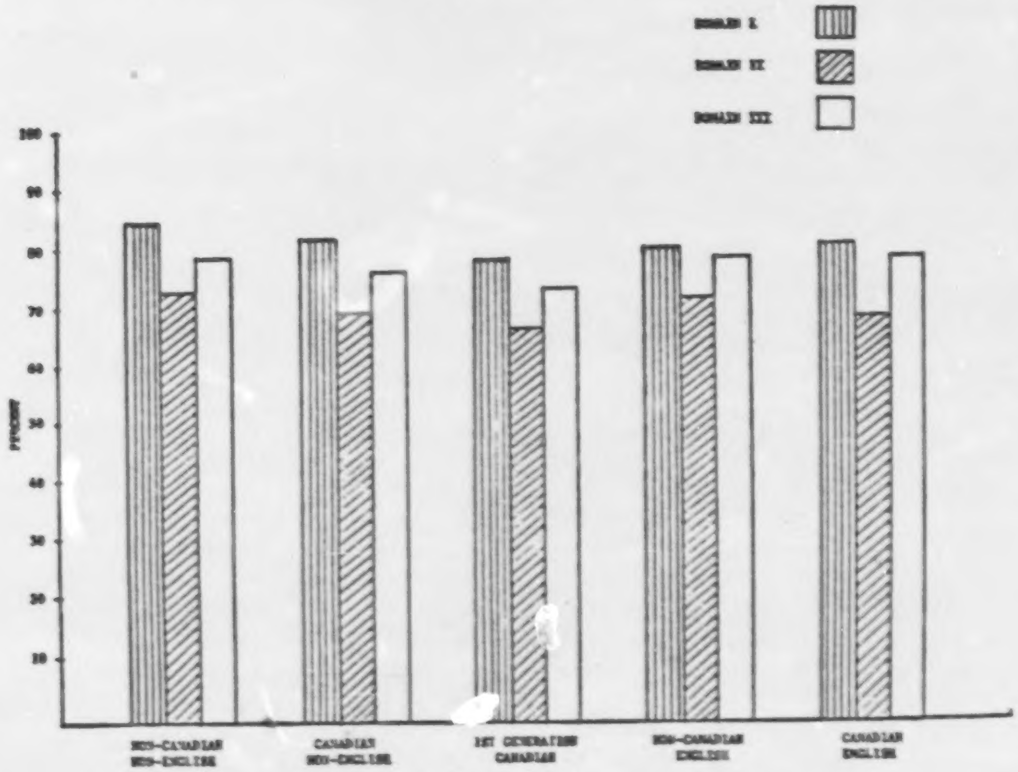


Figure 5-19: Grade 12 Results by Language Group

The Non-Canadian, Non-English group obtained the highest score on all three domains. The First Generation Canadians group scored lowest on all three. As with Grade 8, these results indicate that students who come from a non-English-speaking background have an advantage insofar as mathematics achievement is concerned.

The item shown in Figure 5-20 also appeared on the Grade 12 Reading Assessment test.

About how many hours of television do you watch on an average day during the week?

Usually none .... ☐
Less than 1 hour .... ☐
About 1 hour .... ☐
About 2 hours.............................. ☐
About 3 hours .... ☐
About 4 hours .... ☐
5 hours or more .... ☐

Figure 5-20: Televison Watching Item from the Grade 12 Reading Assessment

The television-watching results were organized into seven groups based on the seven choices shown in the item in Figure 5-20. The results are presented in Figure 5-21.

The data presented in Figure 5-21 show a very distinct pattern with respect to amount of television watched. Those grade 12 students who watched some television but averaged less than one hour per weekday obtained the highest score on all three domains. The performace pattern is very consistent among the Grade 12 students who watched some television: the more television watched, the lower the performance level.

The Grade 12 performance with respect to amount of television watched is identical to the Grade 8 one among students who watched some television. The group of Grade 12 students who responded that they usually watched no television on a weekday performed at a level between the About 1 Hour and About 2 Hours groups, while the analogous group of Grade 8 students had a performance level between the About 3 Hours and About 4 Hours groups.

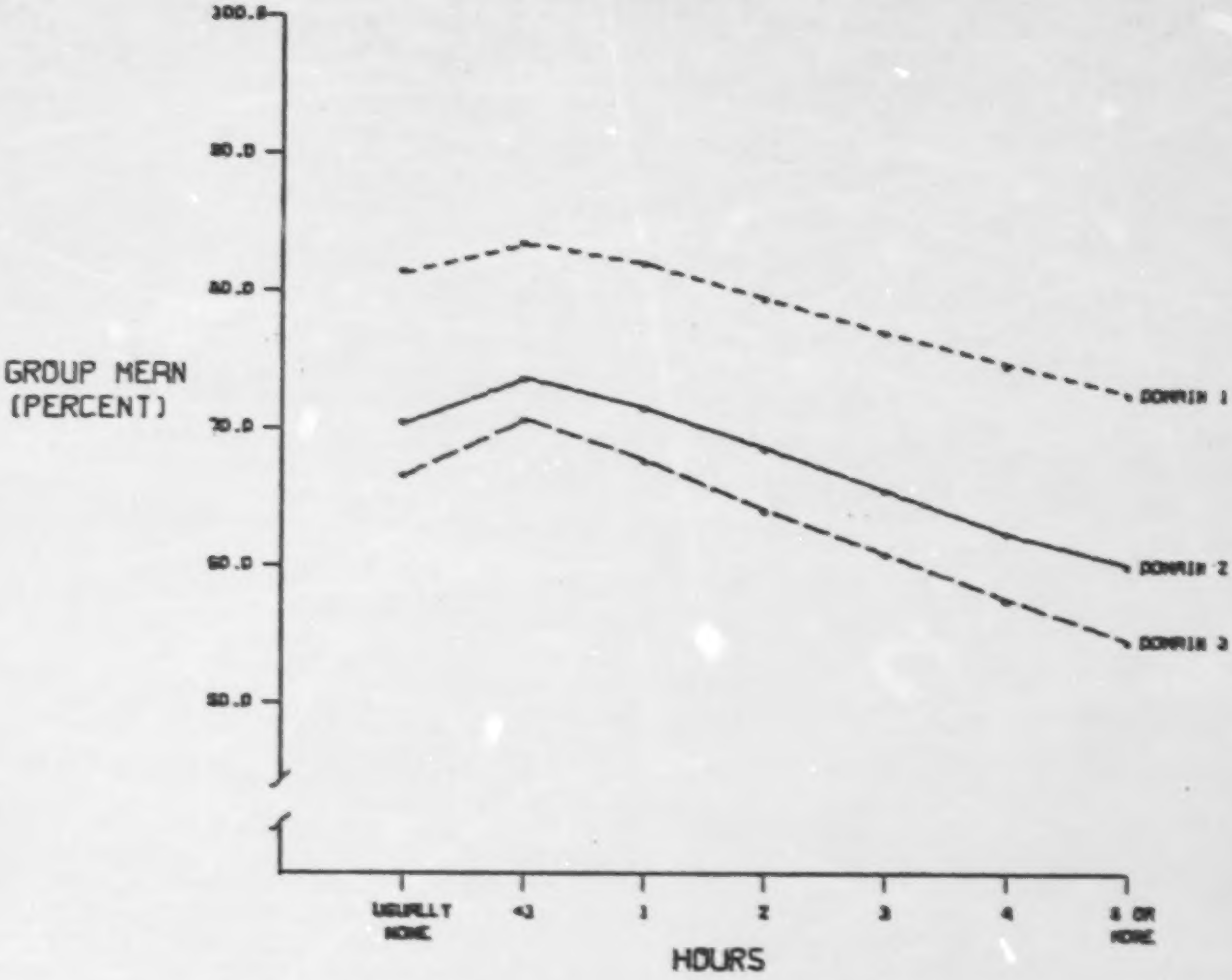


Figure 5-21: Grade 12 Results by Television Watching

The very consistent performace pattern with respect to amount of television watched exhibited in both the Grade 8 and 12 results is very different from the performance pattern exhibited in the results for the Grade/Year four students as presented in Section 3.6 of this report.

5.7.3 Correlation of Reading Results with Mathematics Results

Domain Two of the Reading Assessment was entitled Comprehension as was Domain Two of the Mathematics Assessment. Both tests were attempting to assess comprehension of their respective content areas.

To see if there was a relationship between scores in reading and scores in mathematics, correlations were computed between the four objectives of Domain Two of the Mathematics Assessment and the two objectives of Domain Two of the Reading Assessment.

Since a large majority of the items in the Applications Domain of the Mathematics Assessment required a great deal of reading compared to the other items on the test, correlations between the three objectives of Domain Three of the Mathematics Assessment and the two objectives of Domain Two of the Reading Assessment were also computed. All Fourteen correlations are presented in Table 5-25.

Table 5 - 25

Grade/Year 12: Correlations of Reading and Mathematics Results

Reading Objectives	Mathematics Objectives 2.1	2.2	2.3	2.4	3.1	3.2	3.3
2.1	0.42	0.29	0.35	0.46	0.44	0.41	0.33
2.2	0.37	0.30	0.30	0.41	0.40	0.40	0.29

The test to determine if a correlation is statistically significantly different from zero is dependent upon the size of the sample. Given a sample of size 14 572, any correlation of 0.03 or greater would be statistically significant. Hence, it is more appropriate to talk of educational significance. G. Glass and J. Stanley (1970) present the following categorizations of correlations: if the correlation is less than, or equal to, 0.2, then it should be considered weak; if the correlation is between 0.2 and 0.6, then it should be considered of moderate strength; if the correlation is greater than, or equal to, 0.8, then it should be considered strong.

All of the correlations in Table 5-25 are of moderate strength. Comprehension of algebraic concepts (Objective 2.4) had the highest correlation with both the reading objectives and comprehension of measurement concepts (Objective 2.2) had the lowest correlation with both the reading objectives. The correlations associated with objectives of Domain Three of the Mathematics Assessment averaged about 0.02 higher than those of Domain Two.

5.8 Summary and Recommendations

The Grade 12 test consisted of seventy-two items designed to assess students' mastery of eleven objectives grouped into three domains. In addition to the mathematics items, the test contained fifteen background information items which students were asked to complete before taking the test.

Students responded to all items on the test by shading in the appropriate areas on mark-sense cards which had been specifically designed for the assessment. All items on the test were of the multiple-choice variety. For each item, five foils were given. Of these, four were possible answers to the item and the fifth was "I don't know".

One and one-half hours were alloted for administering the test: thirty minutes for instructions, distribution and collection of the test booklets, and completion of the background information items; sixty minutes for completion of the test itself.

The Grade 12 test was designed to be written by all students enrolled in Grade 12, regardless of their mathematics backgrounds. According to statistics released by the Ministry of Education, the enrollment in Grade 12, as of 28 February, 1977, was 32 532. Of this number, 23 136 (or 71.1% of the total) wrote the test.

5.8.1 Background Information

Based on the data gathered from the fifteen background information questions, over ninety percent of the Grade 12 students were either seventeen or eighteen years old, the normal ages expected. About 800 more females than males wrote the test. While there were more females than males in the Grade 12 group, there were over 1200 more males than females among the thirty-seven percent of the total population who were taking or had taken some form of Mathematics 12. A female majority occurred among those students whose last mathematics course was either Mathematics 10 or 11.

As with the Grades 4 and 8, the data on number of schools attended by students in Grade 12 reflected the high degree of mobility among the general population in B.C. By the time students reached this level they would normally have attended a minimum of two schools, an elementary school and a secondary school, or three schools, an elementary school, a junior secondary school, and a senior secondary school. The results indicated that only about forty percent of Grade 12 students had attended three or fewer schools since starting Grade 1. Unlike Grade 8 students, a majority of Grade 12 students responded that the school they were attending was semestered.

Three questions on the test concerned the use of hand-held calculators. A majority of Grade 12 students responded that they used hand-held calculators in each of the three ways: at home, for homework, and in school.

A majority of the students work at part-time jobs which employ them during the week as well as on weekends. Over one-third of the students plan to go to work full-time upon graduation. About one-third of the students plan to continue their education.

5.8.2 Test Results

The seventy-two items were organized into three domains: Knowledge and Computation (Domain 1, 30 items); Comprehension (Domain 2, 24 items); and Applications (Domain 3, 18 items).

Students' performance on three items in Domain One was rated as a strength while no performance was rated as a weakness. At least ninety percent of the students were able to reduce a fraction to its lowest terms and find the reciprocal of a fraction. The students' ability to recognize that zero is not a factor of twenty-two was rated as a strength in Objective 1.3, Knowledge of Notation and Terminology.

Though there were no weaknesses, several performances were rated as being less than satisfactory. Multiplication and division of decimal fractions, and writing the decimal form of fractions and percents were areas in which the students' performances were rated as marginally satisfactory. On the positive side, their performances in subtraction with fractions and multiplication with fractions and decimals were rated as very satisfactory.

The results on two items from Domain 2 were rated as weaknesses while none of the results in Domain 2 were rated as strengths. However, the performances on ten items for Domain 2 were rated as very satisfactory. The weaknesses occurred on items dealing with fraction concepts and the metric units of mass. The performances that were rated as marginally satisfactory were on items concerning ordering fractions, finding the area of a triangle, finding the slope of a line, simplifying an expression, and finding the amount of simple interest.

The performances that were rated as very satisfactory were on items concerning ordering of decimal fractions, metric units of temperature, capacity, and length, equilateral triangles, finding the volume of a box, evaluating an expression, solving linear and simultaneous equations, and writing a mathematical equation for a word problem.

The Grade 12 students' performance on the eighteen items of Domain 3 was not satisfactory. The results on four items were rated as marginally satisfactory, and the results on five of the items were rated as weaknesses. None of the results were rated as strengths, and only four item results were considered very satisfactory.

There were no weaknesses noted for Objective 3.1, Solve Problems Involving Operations with Whole Numbers, Fractions, Decimals, and Percent, but the results on four items were rated as marginally satisfactory.

The performances on four of the seven items for Objective 3.2, Solve Problems Involving Geometry and Measurement, were noted as weaknesses. The items involved were concerned with finding the area of a square given its perimeter, finding the area of a shaded portion of a rectangle, finding the surface area of a cube, and finding the length of the hypotenuse of a right triangle given the lengths of the other two sides. On three of the four items fewer than fifty percent of the students were able to obtain the correct answer. The other weakness noted for Domain 3 was with an item that involved finding the principal amount given the rate of interest, the time, and the amount of interest.

There were some good performances on items from Domain 3 with over eighty-five percent of the students selecting the correct answer on items concerned with finding an average and finding the amount of a discount.

5.8.3 Reporting Categories

Mathematics achievement is the end result of the coalescing of a great number of student-based factors, both intrinsic and extrinsic. Attributes inherent in the student, programmatic and curricular variables, as well as the effect of environmental variables such as teacher differences, all contribute in varying and largely unknown degree to a given student's overall performance. Of the fairly large number of such variables which the conventional wisdom, current educational practice, and the endeavors of educational researchers have identified as being related to mathematics achievement, the ones selected for scrutiny in the Grade 12 Mathematics Assessment were mathematics background, age, sex, number of schools attended, use of hand-held calculators, semestered versus non-semestered schools, time spent on homework, parental education level, and future plans.

Mathematics Background -- Of the variables selected, this is by far the most important. The results summarized in Section 5.8.2 were for all Grade 12 students, but this group is made of students with very different mathematics backgrounds. For this reason, the data were grouped into three categories: Mathematics 12, those students who had completed or were taking some form of Mathematics 12; Mathematics 11, those students who were taking or whose last mathematics course taken was some form of Mathematics 11; Mathematics 10, those students who were taking or whose last mathematics course taken was some form of Mathematics 10.

The results for this variable produced the expected pattern of performance. Since the Math 12 group had chosen to take mathematics every year they were in school, it was not surprising that they performed at a much higher level than the other two groups. Since the Math 10 group had decided not to take any more mathematics than was required for graduation, it was not surprising that they performed at a much lower level than the other two groups. Domain 1 is the only domain in which the Mathematics 10 group performed above the 50 percent level, and in this domain they performed at lower than the 50 percent level on twelve of the thirty items. The Math 10 group averaged less than fifty percent correct on over half of the items on the test while the Math 12 group averaged less than fifty percent correct on only one item of the seventy-two.

Age Differences -- The general pattern was that performance decreased with an increase in age. The pattern held for every objective.

Sex Differences -- Males outperformed females on nine of the eleven objectives. The two objectives where the females did obtain the higher performance were in Domain 1, the least complex cognitive behaviour.

Number of Schools Attended -- This variable appeared to be unrelated to mathematics achievement at the Grade 12 level.

Use of Hand-Held Calculators -- The data were organized according to the response on each of three items concerning the use of hand-held calculators at home, in school, and for homework. In all three cases the results were the same: students who used hand-held calculators outperformed the students who did not use hand-held calculators on every objective.

Time Spent on Homework -- Only the data on those Grade 12 students who were taking a mathematics course at the time of the Mathematics Assessment were analyzed for this variable. About two out of every thirty Math 12 students and two out of every five Math 10 students responded that they spent no out-of-class time on mathematics assignments. The group of Grade 12 students that spent no time at all on mathematics homework had the lowest performance on every objective. The differences were small but the trend was very clear. Math 12 students who spent some time, but less than thirty minutes per day, on mathematics homework had the highest performance on every objective and the analogous group of Math 11 students had the highest performance on ten of the eleven objectives.

Parental Education Level -- The pattern was clear: the more education each parent had, the higher the performance. An exception was noted in the case of the group whose parents had completed junior secondary school. They performed at a lower level than the group whose parents had completed only elementary school.

Future Plans -- Students planning to attend university performed at the highest level on all objectives. Students planning to look for jobs performed at the lowest level on ten of the eleven objectives.

5.8.4 Data from the Reading Assessment

In addition to the Mathematics test, an assessment test in Reading was also given at the Grade 12 level. These two tests contained similar, and in some cases identical, background information questions. On both the Mathematics and Reading tests, students were asked their birthdate, sex, and number of schools attended. Using the common information, a computer search was able to match the complete reading and mathematics data for sixty-three percent of the Grade 12 students. A data file was created to contain the information and results on both tests for the matched students so that comparisons between their performances on the tests could be made. The two reporting categories from the Grade 12 Reading Assessment which were presented concerned language and television watching.

Language -- The Grade 12 data were grouped according to whether the students had been born in Canada, whether they usually spoke a language other than English before starting Grade 1, and whether English was the language usually spoken in the home. The non-Canadian non-English-speaking group obtained the highest results in each domain.

Television Watching -- Grade 12 students who watched some but less than one hour of television per weekday had the best performance on every objective. The pattern among the data was that the more television watched, the lower the performance on the Mathematics Assessment test. The no television group ranked between the about one hour and about two hours groups.

5.8.5 Recommendations

Based on the data presented in this chapter, the following recommendations were made.

Recommendation 5-1: The Ministry of Education should institute a program of research designed to ascertain why such a high proportion of female students do not continue to study mathematics beyond the last compulsory course.

Recommendation 5-2: On the basis of the evidence obtained as a result of the implementation of Recommendation 1, the Ministry of Education, in cooperation with local school districts and teachers' groups, should institute professional development programs to sensitize teachers and counsellors to this tendency and with ways of dealing with it.

Recommendation 5-3: The Curriculum Development Branch should consider the impact of the use of hand-held calculators in mathematics classrooms at various levels: primary; intermediate; junior secondary; and senior secondary. The Committee should provide guidance and direction to teachers of mathematics regarding the most appropriate uses of such calculators in their teaching.

Recommendation 5-4: *Schools and school districts should implement programs to familiarize all of their students, but especially those at the senior secondary level, with the basic concepts and principles of the metric system of measurement.*

Recommendation 5-5: *The Curriculum Development Branch should examine the situation with regard to the teaching of percent and its applications, and give specific suggestions to teachers regarding appropriate materials and methods to be used in teaching these topics.*

Recommendation 5-6: *Teachers and teacher educators should stress the overriding importance of problem solving in mathematics and they should attempt to teach their students various strategies to employ in attempting to solve problems in mathematics.*

Recommendation 5-7: *Individual teachers and mathematics departments should set up their own collections of problems and activities out of which problems grow, keeping in mind the interests of their students and making use of local information in order that their problems will be more interesting to students.*

Recommendation 5-8: *The Curriculum Development Branch should give immediate and serious consideration to ways and means of ensuring that all students completing Grade 12 have been taught the major topics of consumer mathematics.*

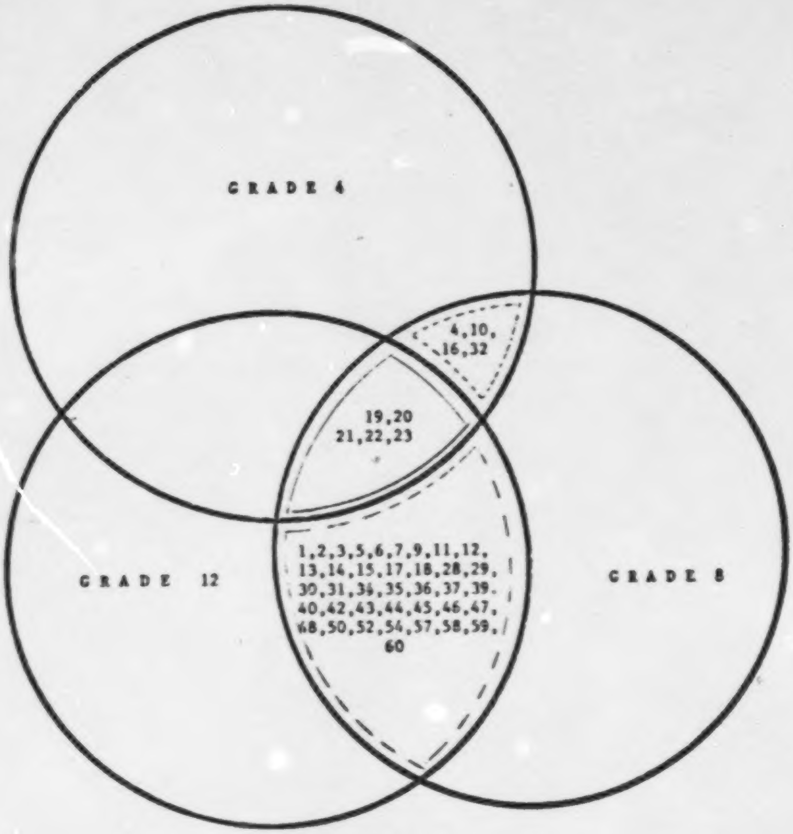
Recommendation 5-9: *The Curriculum Development Branch should reconsider the nature and scope of the geometry curriculum at the secondary school level, keeping in mind the results obtained by the students on the geometry items on this test.*

Chapter 6

GRADES 4, 8, 12: COMMON ITEMS

Many of the skills and concepts of mathematics which are learned in one grade continue to be useful and important in subsequent years. Moreover, it is often the case that when such concepts or skills are introduced for the first time, mastery is not expected. Instead, since teachers and curriculum developers know that the topic will be re-introduced later, only certain aspects are dealt with each time and only a certain degree of mastery is expected. In other words, since mathematics is developmental and highly sequential in nature, a degree of development in students' ability to deal with various concepts and skills is not only to be expected but desired.

In order to obtain information about development of students' mastery of such topics, a number of items were repeated on two or, in some cases, all three of the tests. Nine items were repeated on Grade 4 and 8 tests, forty-three items on the Grade 8 and 12 tests. Of the items that appeared on more than one test, five appeared on all three. Figure 6-1 presents the distribution of the common test items as the items are numbered on the Grade 8 test.



(The items are numbered as they appear on the Grade 8 test.)

Figure 6-1: Distribution of Common Test Items

6.1 Items Common to All Three Tests

The five items appearing on all three tests measured students' knowledge and understanding of the units of the metric system of measurement. Results for these five items appear in Table 6-1

Table 6-1
Results on Items Common To All Three Tests

Item No.	Topic	Grade/Year 4	Grade 8	Grade 12
19*	temperature	32	69	87
20	conversion	49	69	63
21	capacity	67	84	90
22	mass	25	45	54
23	length	81	84	82
Average		50.8	70.2	75.2

* Items are numbered as they appear on Grade 8 Test

According to the Curriculum Guide for Mathematics, students in Grade/Year 4 should have been taught the metric system of measurement and only the metric system since they entered school. In spite of this only 32% of the Grade/Year 4 students chose the appropriate temperature for a sunny summer day and only 25% were able to select the appropriate mass for a ten-year-old boy. One cause for the much better performance at the higher grade levels may be the exposure the public has been receiving concerning the metric units through the communications media. Item 19, below, is a good example.

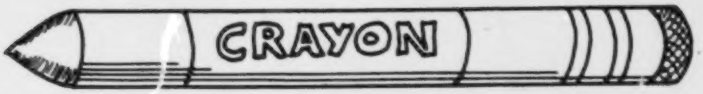
19. The temperature on a sunny summer day would most likely be:	Grade/Year 4	Grade 8	Grade 12
A) 5 Celsius	5	5	3
B) 25 Celsius	32	69	87
C) 55 Celsius	27	12	5
D) 85 Celsius	29	9	3
E) I don't know	6	4	2
No Response	1	1	1

Figure 6-2: Common Item (degrees Celsius)

Canada has been using degrees Celsius for temperature for over two years, a longer period than for any of the other new units. While the degree Celsius is the unit that should be most familiar to the Canadian people, Item 19 yielded the most drastic differences among the three groups of all five items which dealt with metric measurement. It may be that Grade 8 and 12 students are more knowledgeable about temperature in degrees Celsius simply because they are more aware of the day-to-day temperatures which are reported in these terms.

All three groups performed equally well on Item 23, shown in Figure 6-3 which dealt with units of length in metric system.

23. About how long is this crayon?



		Grade/Year 4	Grade 8	Grade 12
A)	1 centimetre	4	2	3
B)	10 centimetres	81	84	82
C)	1 metre	5	6	4
D)	10 metres	5	4	4
E)	I don't know	4	3	7
	No Response	1	1	1

Figure 6-3: Common Item (length)

The centimetre is one of the first metric units introduced in the primary grades, and all of the mathematics textbooks used in the primary grades suggest experiences analogous to that in Item 23. All three Interpretation Panels were satisfied with the students' performance on Item 23.

6.2 Items Common to the Grade 4 and 8 Tests

Four items, Items 4, 10, 16 and 32, were used on both the Grade 4 and 8 tests. The results obtained by the two groups on these items are summarized in Table 6-2.

Table 6-2
Results on Items in Common to the Grade 4 and 8 Tests

Item No.	Topic	Grade/Year 4	Grade 8
4	addition	89	93
10	place value	88	90
16	subtraction	56	89
32	addition (money)	80	88
Average		78.2	90.0

Three of the four items, all but Item 10, were presented as open-ended exercises on the Grade/Year 4 test, whereas all of the items on the Grade 8 test were multiple-choice. Because of this, any comparison between the results of the two groups of students should be made with caution since the format of the items may have influenced student performance. Comparison, however, is made easier by the fact that on Items 4 and 32 both groups performed very well.

The Interpretation Panels for both grades were pleased with the performaces on Items 4, 10 and 32, and the Grade 8 Panel was very satisfied with the Grade 8 students' performance on Item 16. The results on Item 36 of the Grade/Year 4 test, the same item as Item 16 on the Grade 8 test, were judged to be a weakness by the Panel for that grade. A complete discussion of the results on that item may be found in Section 3.3.3.

6.3 Items Common to the Grade 8 and 12 Tests

Forty-three of the items on the Grade 8 test, including the five metric items discussed in Section 6.1, also appeared on the Grade 12 test. The results obtained on these items are discussed in this section which is organized according to the Grade 8 list of objectives. For each objective the following information is provided:

1) the item numbers for the common items from the Grade 8 and 12 tests
2) the item results for four groups of students, Math 8, Math 10, Math 11 and Math 12
3) the average percent correct for the common items on that objective, and
4) the number of items used to assess that objective.

Items which were common to these two tests had been given identical item numbers so that comparison between tests would be facilitated.

All students who took the Grade 12 test were enrolled in Grade 12, but not all of them were taking Math 12. For that reason, the Grade 12 results presented in this section are organized by three groups of students: those students who had completed or were taking some form of Math 12 (Math 12), those students who were taking or whose highest mathematics course completed was some form of Math 11 (Math 11), and those students who were taking or whose highest mathematics course completed was some form of Math 10 (Math 10). The fourth group of students discussed in this section included everyone who took the Grade 8 test (Math 8).

The number of items used to assess an objective is given since the following three situations arise: 1) the common items and the items used to assess an objective are identical, 2) the same number of items are used on each test to assess an objective and the common items are a proper subset. As a result, the average on a set of common items for an objective may differ from the average for the objective reported in Chapter 4 or 5 because it is based on a different set of data. Decisions or judgments regarding the degree of success attained by a group of students on a given objective should be based upon their performance on the complete set of items used to assess that objective and not on a subset of them. The discussion in this chapter will therefore focus on a comparison of groups' performance relative to each other and not on any single group's performance on an objective.

None of the items used to evaluate the objective, Computation with Whole Numbers, on the Grade 8 test were repeated on the Grade 12 test. For that reason, presentation of the results of the items common to the Grade 8 and 12 tests begins with Computation with Fractions.

6.3.1 Objective: Computation with Fractions

The four items used to assess this objective on the Grade 8 test were also used on the Grade 12 test. The results for these items are presented in Table 6-3.

Table 6-3
Results for Items Common to the Grade 8 and 12 Test
Objective*: Computation with Fractions

Item	Operation	Percent Correct:			
		Math 8	Math 10	Math 11	Math 12
2	Addition	66	67	84	98
6	Subtraction	63	67	84	96
11	Division	62	47	70	91
29	Multiplication	82	74	85	96
Average		68.2	63.8	80.8	95.2

* The objective was assessed by four items on each test.

It is not surprising that the Math 11 and Math 12 groups scored significantly higher than the Math 8 and Math 10 groups on this or any other set of items, since the students in Math 11 and Math 12 are, generally speaking, the most capable and most interested mathematics students. As might well be expected on this objective, which is from the lowest cognitive behaviour, the Math 12 performance was very high.

Those Grade 12 students whose last mathematics course was some form of Math 10 had a lower average performance than the Grade 8 students on this objective. The Math 10 group out-performed the Math 8 group on addition and subtraction items, but the Math 8 was superior on the multiplication and division items.

6.3.2 Objective: Computation with Decimals

The same five items were used to assess this objective on both the Grade 8 and 12 tests. The students' performance on these items is summarized in Table 6-4.

The general pattern of performance seems to be the same for computation with fractions. It is interesting to note that the performance of the Math 10 group is the only one that is higher on this objective than on the previous one. The Math 8 group still outperformed the Math 10 group, however, and the Math 12 group performed above the 90% level. Compared to the performance on computation with fractions, the Math 8 and Math 10 groups performed at a level which was closer to, but still distant from, the Math 11 group.

Table 6-4
Results for Items Common to the Grade 8 and 12 Tests
Objective*: Computation with Decimals

		Percent Correct:			
Item	Operation	Math 8	Math 10	Math 11	Math 12
1	Subtraction	79	78	85	93
5	Multiplication	63	57	74	92
15	Addition	72	75	83	90
17	Subtraction	66	71	84	95
28	Division	58	44	60	82
Average:		67.6	65.0	77.2	90.4

* The objective was assessed by five items on each test.

All three groups at the Grade 12 level seemed not to be affected by the "ragged alignment" factor in Item 17. The difference in performance between Item 1 and Item 17, both involving subtraction of decimals in horizontal form, was seven percent for Math 10, one percent for Math 11, and a two percent increase for Math 12. The Math 8 performance dropped thirteen percent between the two items.

6.3.3 Objective: Knowledge of Notation and Terminology

Fourteen items were used to assess students' knowledge of notation and terminology on the Grade 12 test, and nine were used on the Grade 8 test. Of these, eight items were common to both tests. The results obtained on the common items are displayed in Table 6-5.

Table 6-5
Results for Items Common to the Grade 8 and 12 Tests
Objective*: Knowledge of Notation and Terminology

		Percent Correct:			
Item	Topic	Math 8	Math 10	Math 11	Math 12
3	Square Root	51	62	87	99
7	Factor	78	71	83	96
9	Powers of 10	73	56	71	87
20	Centimetres	69	38	55	85
30	Exponents	72	67	88	96
34	G.C.F.	73	66	75	87
44	Reciprocal	80	74	89	98
45	Prime Numbers	53	38	60	84
Average:		68.6	59.0	76.0	91.5

*The objective was assessed by nine items on Grade 8 test and fourteen items on the Grade 12 test.

All three Grade 12 groups recorded their lowest performance of the eight items on Item 45, identifying a prime number. The Math 8 group's performance on Item 3 was the only one of the eight items on which they performed lower than Item 45. The Math 10 group performed equally poorly on Item 20, converting 5 metres to centimetres. The Math 8 performance on Item 20 was second only to that of the Math 12 groups.

Once again the Math 8 group's performance was higher than that of the Math 10 group, and the Math 12 group continued to perform above the ninety percent level.

6.3.4. Other Common Items from Domain One

Because the tests were designed for use at three different grade levels, some items which were repeated were classified with different objectives on different tests. There were seven such items. Three of the items used to assess Knowledge of Geometric Facts on the Grade 8 test were used to assess Knowledge of Notation and Terminology on the Grade 12 test. The results for those three items are found in Table 6-6.

Table 6-6
Results for Items Common to the Grade 8 and 12 Tests
Objective (Grade 8): Knowledge of Geometric Facts
Objective (Grade 12): Knowledge of Notation and Terminology

		Percent Correct:			
Item	Topic	Math 8	Math 10	Math 11	Math 12
39	Obtuse Angle	40	35	51	88
40	Diameter	63	66	77	86
42	Sphere	72	80	87	95
Average:		58.3	60.3	71.7	89.7

The Math 12 group's performance is slightly below the ninety percent level, but the performance is still high, as would be expected. The Math 10 group outperformed the Math 8 group on these three items on the average.

All three lower groups had difficulty with Item 39, recognizing an obtuse angle. Whether or not the classifying of angles as acute, right, and obtuse is taught or is perceived as being important by students and teachers cannot be determined from the data.

Four of the items used to assess Equivalent Forms of Rational Numbers on the Grade 8 test were used for Knowledge of Other Algorithms on the Grade 12 test. The results for the four items are presented in Table 6-7.

Table 6-7
Results for Items Common to the Grade 8 and 12 Tests
Objective (Grade 8): Equivalent Forms of Rational Numbers
Objective (Grade 12): Knowledge of Other Algorithms

Item	Topic	Percent Correct: Math 8	Math 10	Math 11	Math 12
13	Fraction to Percent	55	56	75	94
31	Fraction to Decimal	38	42	61	87
35	Percent to Decimal	47	39	57	86
46	Reducing Fraction	80	84	91	97
Average:		55.0	55.2	71.0	91.0

The results of these last four items of Domain 1 that are common to the Grade 8 and 12 tests follow the same basic pattern as for the other objectives. The Math 12 group performed at above the ninety percent level, Math 8 and Math 10 performed at similar levels, and Math 11 performed at a level between the Math 12 performance level and that of the Math 8 and Math 10 groups.

Recommendation 6-1: Secondary mathematics teachers should work to improve the Math 8, Math 10, and Math 11 students' performance on the use of algorithms for rational numbers: the four basic operations with fractions, the four basic operations with decimals, and equivalent forms of rational numbers.

Figure 6-4 presents graphically what has been stated in the discussion: the Math 12 group's performance was above the ninety percent level, far superior to the other groups; the Math 11 group's performance was around the seventy-five percent level, well above the performance of the lower two groups. The Math 8 and 10 groups' performances were very similar and low.

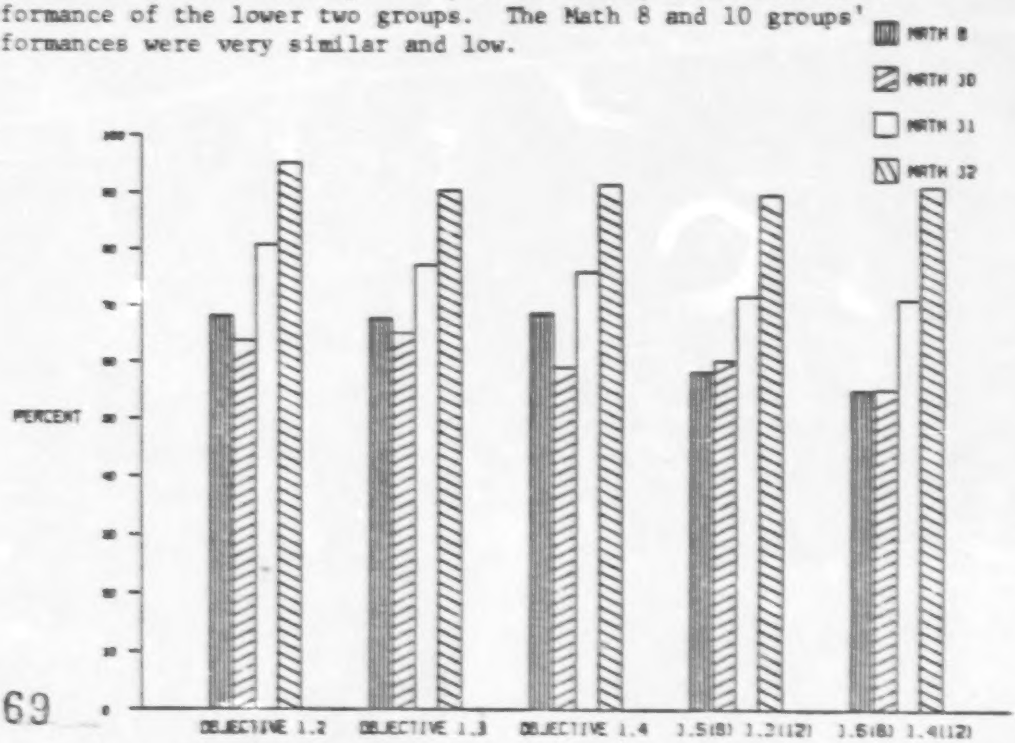


Figure 6-4: Grade 8 and 12 Results of Common Items, Domain 1

6.3.5 Objective: Comprehension of Number Concepts

On both the Grade 8 and 12 tests six items were used to assess Comprehension of Number Concepts. Of the six items, five were common to both tests. The results for the five items are presented in Table 6-8

Table 6-8
Results for Items Common to the Grade 8 and 12 Tests
Objective*: Comprehension of Number Concepts

	Percent Correct:			
Item	Math 8	Math 10	Math 11	Math 12
12	42	44	55	78
14	69	78	83	94
18	32	35	45	66
47	29	37	51	79
50	59	60	71	87
Average:	46.2	50.8	61.0	80.8

* The objective was assessed by six items on each test.

As has been noted in the three preceeding chapters, performance levels tend to decrease as the cognitive behaviour (domain) level increases. This tendency is also true among the three subgroups at the Grade 12 level, as is evident from the results shown in Table 6-8.

The patterns of performance for each group relative to the other three remain the same as they were for the objectives of Domain 1, with the Math 12 performance being far superior to the others. The Math 8 and Math 10 groups continued to perform about equally well. Students from all four groups had more difficulty with Item 18 than with any of the other items in this group. Item 18 and a discussion of the results are presented in Section 4.4.1 for Grade 8 and Section 5.4.1 for Grade 12. Only the Math 12 group obtained a result higher than fifty percent on this item, and their score was twelve percent less on this item than their next lowest score.

6.3.6 Objective: Comprehension of Measurement Concepts

The five items used to assess mastery of measurement concepts on the Grade 8 test were also used to assess the same objective on the Grade 12 test. The results for these five items are presented in Table 6-9.

Items 19, 21, 22, and 23 also appeared on the Grade/Year 4 test and were discussed in section 6.1 of this chapter. The pattern of overall performance portrayed here is basically the same. The Math 10 group outperformed the Math 8 group by eleven percent on Item 19, the metric temperature item, but it is not possible to tell from the data whether that superior performance was due to school-based factors or to the exposure to the new unit of measurement for temperature on a day-to-day basis.

Table 6-9
Results for Items Common to the Grade 8 and 12 Tests
Objective*: Comprehension of Measurement Concepts

Items	Percent Correct: Math 8	Math 10	Math 11	Math 12
19	69	80	86	92
21	84	82	89	96
22	45	40	49	67
23	84	65	79	93
43	65	63	78	94
Average	69.4	66.0	76.2	88.4

* The objective was assessed by five items on each test.

The centimetre, on the other hand, is one of the first metric units introduced in schools and is used only in a very limited way in today's society. The Math 8 group outperformed the Math 10 group and the Math 11 group on Item 23, the metric length item.

Recommendation 6-2: Teachers of mathematics, curriculum developers, and teacher educators should cooperate in starting both pre-service and in-service efforts to ensure that all students receive proper instruction in all the facets of the metric system of measurement needed to be a functioning member of Canadian society.

6.3.7 Objective: Comprehension of Geometric Concepts

The Grade 8 and 12 tests each included four items to assess Comprehension of Geometric Concepts. Two of the four items were common to both tests, and the results for these two items are presented in Table 6-10.

Table 6-10
Results for Items Common to the Grade 8 and 12 Tests
Objective*: Comprehension of Geometric Concepts

Items	Percent Correct: Math 8	Math 10	Math 11	Math 12
52	24	24	42	83
54	63	66	78	92
Average:	43.5	45.0	60.0	87.5

*The objective was assessed by four items on each test.

One of the most startling results was produced on Item 52, finding the area of a right triangle. Item 52 and a discussion of the results are presented in Section 4.4.3 for Grade 8 and Section 5.4.3 for Grade 12. This item involved the use of the formula for the area of a triangle, one of the most simple and useful geometric formulas. On Item 54, which required students to find the volume of a box measuring 6x5x8, the Math 10 group outperformed the Math 8 group by only three percent.

Recommendation 6-3: Curriculum developers and secondary mathematics teachers should ensure that the basic formulas for area and volume are presented and understood by all students.

6.3.8 Objective: Comprehension of Algebraic Concepts

Nine algebraic concept items were included on the Grade 12 test and three on the Grade 8 test. Two items were common to both tests, and these are discussed in Table 6-11.

Table 6-11
Results for Items Common to the Grade 8 and 12 Tests
Objective*: Comprehension of Algebraic Concepts

	Percent Correct:			
Items	Math 8	Math 10	Math 11	Math 12
48	18	32	58	92
57	68	70	82	88
Average:	43.0	51.0	70.0	90.0

* This objective was assessed by three items on the Grade 8 test and seven items on the Grade 12 test.

The performance on this objective is close to what might have been expected. The Math 8 group scored low, but they had only begun to use algebraic concepts in the more formal mathematical sense. The Math 10 group scores were low, but higher than those of the Math 8 group. The Math 11 group scored nineteen percent higher than Math 10 and twenty percent lower than Math 12. Item 48, which dealt with order of operations, yielded a much lower performance than was anticipated. The results for Item 48 obtained by the Math 8 group are discussed in Section 4.4.4 of this report and the results of Item 48 for the Grade 12 group are discussed in Section 5.4.4.

The pattern of performance for the four groups on the common items of Domain 2 are presented in Figure 6-5.

When comparing the performance of a group with respect to the other three groups, the results are analogous to those presented for the common items of Domain 1. The Math 12 group's performance was an average of twenty percent greater than the Math 11 group's which, in turn, was an average of thirteen percent greater than the lower two groups. The Math 8 and 10 groups' performances were low and had an average difference of less than one percent.

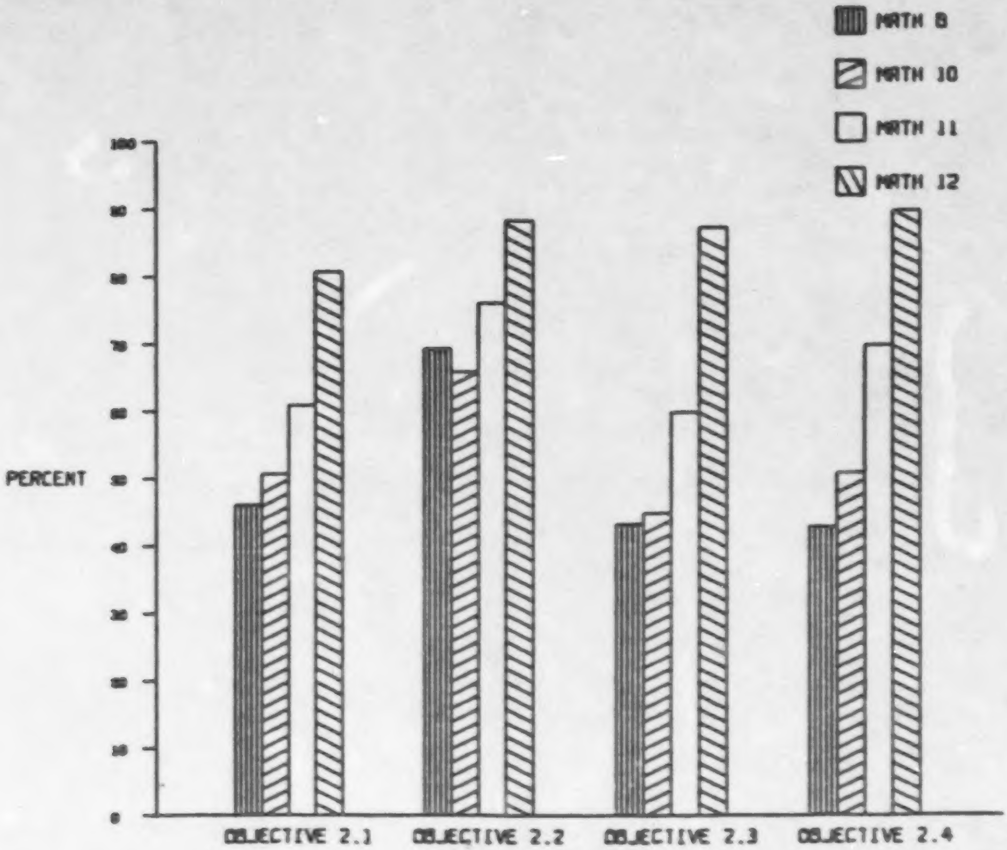


Figure 6-5: Grade 8 and 12 Results of Common Items - Domain 2

6.3.9 Objective: Solve Problems Involving Different Sets of Numbers

Of the seven items used to assess this objective on the Grade 8 test, three items were repeated on the Grade 12 test where nine items were used to assess the objective. The results for the three items in common to both tests are presented in Table 6-12. On this objective, the results were similar to those for Comprehension of Algebraic Concepts in that the performance level increased for each succeeding group.

Table 6-12
Results for Items Common to the Grade 8 and 12 Tests
Objective*: Solve Problems Involving Different Sets of Numbers

	Percent Correct:			
Item	Math 8	Math 10	Math 11	Math 12
58	68	75	85	95
59	57	63	75	91
60	38	41	58	86
Average:	53.7	59.7	72.7	90.7

* This objective was assessed by seven items on the Grade 8 test and nine items on the Grade 12 test.

The item that yielded the lowest performance, Item 60, was a multi-step problem. The item and a discussion of the results appear in Sections 4.5.1 (Grade 8) and 5.5.1 (Grade 12) of this report. It seems likely that students who did the problem incorrectly did so because they tried to turn it into a one-step problem. On both tests the students selecting an incorrect distractor were evenly split between distractors B and D. Both of these distractors are based on students combining two percents and using the results as the number of students.

6.3.10 Objective: Solving Problems Involving Geometry and Measurement

There were three items on the Grade 8 test and seven items on the Grade 12 test used to assess students' ability to solve geometry and measurement problems from the Applications Domain of the Mathematics Assessment. Two of the items were used on both tests. The results for those two items are presented in Table 6-13.

Table 6-13
Results for Items Common to the Grade 8 and 12 Tests
Objective*: Solve Problems Involving Geometry and Measurement

	Percent Correct:			
Item	Math 8	Math 10	Math 11	Math 12
36	66	61	78	94
37	27	27	44	79
Average:	46.5	44.0	61.0	86.5

*This objective was assessed by three items on the Grade 8 test and seven items on the Grade 12 test.

A more common performance pattern prevails for the two common items from this objective. Math 8 and Math 10 performed at similar levels, Math 11 between the two other Grade 12 groups, and Math 12 some twenty-five percent higher than the next highest group.

Item 37 obviously caused considerable difficulty for everyone. The item and a discussion of the results for the item may be found in Sections 4.5.2.

The performance pattern for the four groups on the common items of Domain 3 are presented in Figure 6-6. The same pattern exists for the common items of Domain 3 as did for Domains 1 and 2. The Math 12 group performed an average of twenty-two percent higher than the Math 11 group which performed fifteen percent better than the lower two groups. The Math 8 and 10 groups' performances differed by less than two percent.

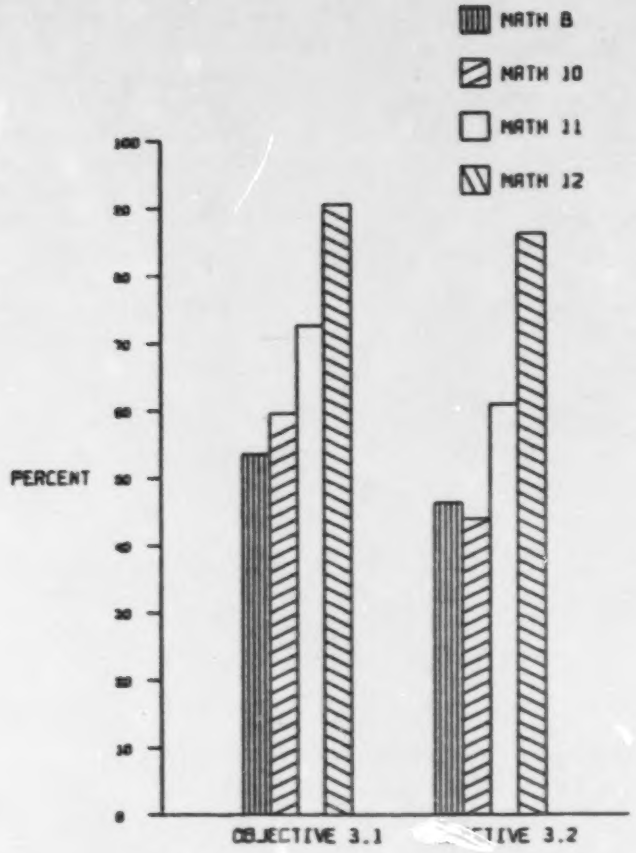


Figure 6-6: Grade 8 and 12 Results of Common Items - Domain 3

6.4 Summary and Recommendations

One of the aims of the Mathematics Assessment was to gather data which would give some insight into the development of students' abilities to deal with certain concepts and skills. To gather data relevant to this aim, a number of the same items appeared on two or more of the tests.

Five items were common to all three tests. These were concerned with knowledge and understanding of the units of the metric system of measurement. The Grade 8 and 12 groups consistently scored higher than the Grade/Year 4 group. On the metric length items the three grade levels were separated by only three percentage points.

There were four items that appeared on the Grade 4 and 8 tests, but not the Grade 12 test. On three of the four items both groups scored at the eighty percent level or higher. On Item 16 the Grade 8 group scored one third higher than the Grade/Year 4 group but Item 16 was open-ended on the latter test and multiple-choice on the former, which may account for some of the difference in performance.

There were forty-three items common to the Grade 8 and 12 tests. Due to the large number, the results for the items were organized and discussed by objective.

The Grade 12 group was divided into three subgroups: Math 12, students who are taking or have completed some form of Mathematics 12; Math 11, those students taking or whose highest mathematics course completed is some form of Mathematics 11; and Math 10, those students taking or whose highest mathematics course completed is some form of Mathematics 10. The Math 8 group included everyone who took the Grade 8 test.

The mean performance of each of the four groups for the items common to the Grade 8 and 12 tests, organized by Domain is presented in Figure 6-7.

Some very clear patterns of performance are illustrated in Figure 6-7. The Math 12 group, as would be hoped, performed well on all three domains and averaged more than eighteen percent higher than the next highest group. The Math 11 group's performance was in the middle, eighteen percent below Math 12 and fourteen percent above the lower two groups. The most significant pattern in Figure 6-7, however, is that the Math 10 group's performance was no higher than the Math 8 group's performance.

The relative position of Math 10, Math 11, and Math 12 among the three groups is not surprising. The Math 12 group should be the best of the three since the group consists of those students who have elected to take mathematics every year. The Math 11 group includes students who have elected to take one more mathematics course than is required for secondary school graduation. The Math 10 students have either decided to take no more mathematics than is required, or have been incapable of continuing beyond the minimum level required for graduation.

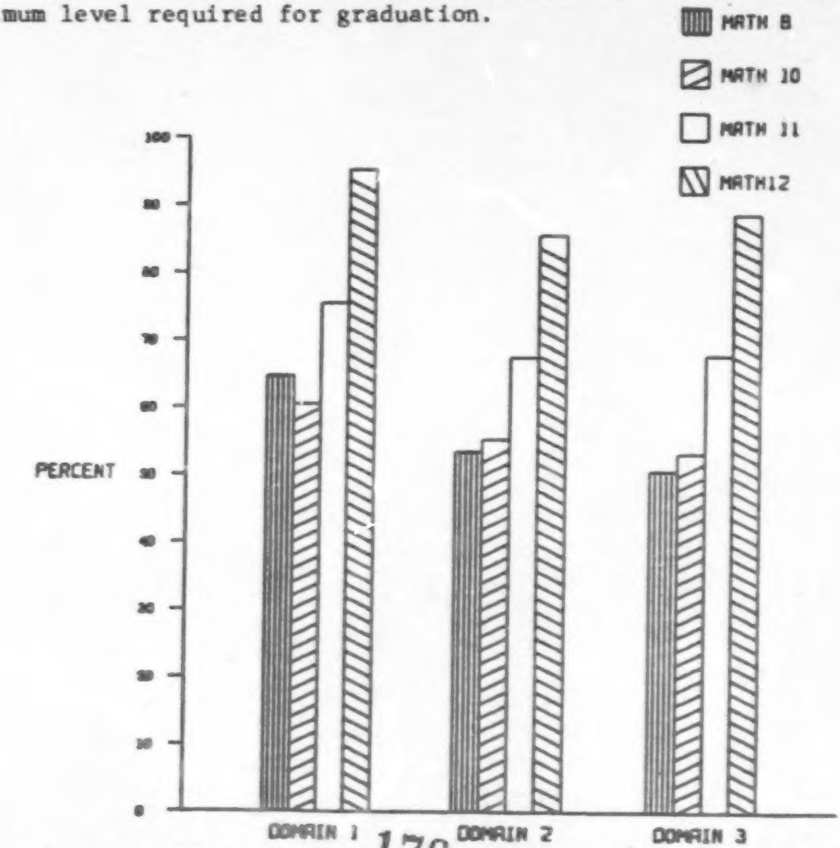


Figure 6-7: Grade 8 and 12 Results of Common Items Summary

Asked about their future plans, the response category most commonly selected by the Math 10 group was "Look for a job". As the students in the Math 10 group seek employment, they are assumed to have certain skills as graduates of the school system. Among those skills is a mastery of the essential skills of mathematics. Society's judgment of their level of mastery of those skills is delayed until the students enter the job market upon graduation from secondary school. If it can be assumed that the judgment is based, in part, on skills learned during grades 9 and 10 and that the desired level is higher than the sixty percent level of actual performance, then it should be a matter of some concern that, upon graduation, the Math 10 group's performance is no higher than that of the Math 8 group.

Based upon results described in this chapter several recommendations are presented. Many recommendations have been made in Chapter 4 for the Grade 8 group and in Chapter 5 for the Grade 12 group.

Recommendation 6-1: Secondary mathematics teachers should work to improve the Math 8, Math 10, and Math 11 students' performance on the use of algorithms for rational numbers: the four basic operations with fractions, the four basic operations with decimals, and equipvalent forms of rational numbers.

Recommendation 6-2: Teachers of mathematics, curriculum developers, and teacher educators should co-operate in starting both pre-service and in-service efforts to ensure that all students receive proper instruction in all the facets of the metric system of measurement needed to be a functioning member of Canadian society.

Recommendation 6-3: Curriculum developers and secondary mathematics teachers should ensure that the basic formulas for area and volume are presented to and understood by all students.

Appendix A: Schools Participating in the Pilot Testing for the Mathematics Assessment

SCHOOLS OF THE PILOT TESTING

The authors of this report are very grateful to the administrators and staff of the following schools which participated in piloting the student tests in the autumn of 1976.

Grade 4 Piloting

Douglas Road Elementary, Burnaby School District
Hillcrest Elementary, Coquitlam School District
King George V Elementary, Prince George School District
Lakeview Elementary, Burnaby School District
MacDonald Elementary, Vancouver School District
Muriel Baxter Elementary, Cranbrook School District
Sir William Van Horne Elementary, Vancouver School District

Grade 8 Piloting

Alpha Secondary, Burnaby School District
Connaught Junior Secondary, Prince George School District
Gladstone Secondary, Vancouver School District
Handsworth Secondary, North Vancouver School District
Kitsilano Secondary, Vancouver School District
Laurie Junior Secondary, Cranbrook School District
Mary Hill Junior Secondary, Coquitlam School District

Grade 12 Piloting

Alpha Secondary, Burnaby School District
Gladstone Secondary, Vancouver School District
Handsworth Secondary, North Vancouver School District
Kelly Road Secondary, Prince George School District
Kitsilano Secondary, Vancouver School District
Mount Baker Secondary, Cranbrook School District
Port Moody Senior Secondary, Coquitlam School District

Appendix B: Mathematics Assessment Review Panels

MATHEMATICS REVIEW PANELS

Review panels comprised of educators and members of the lay public were organized in the autumn of 1976 at four provincial centres to examine and amend the proposed objectives of the mathematics assessment before the student tests were developed.

CASTLEGAR REVIEW PANEL

Mr. Jack Allen, Supervisor
Cranbrook School District

Mr. Larry Cerny, Teacher
Fernie School District

Ms. Sheila Crane, Teacher
Arrow Lakes School District

Mr. Jack Edson, Teacher
Nelson School District

Mr. Dale Fike, Personnel Officer
Cominco, Trail

Mr. Bruce Gerrard, Teacher
Castlegar School District

Mr. Tom Gougeon, Teacher
Castlegar School District

Mr. Tom Johnson, Teacher
Nelson School District

Ms. Joan Knowles, Teacher
Castlegar School District

Mr. Peter Makiev, Teacher
Nelson School District

Mr. Gary Mitchell, Teacher
Cranbrook School District

Mr. Bruce Morrison, Teacher
Arrow Lakes School District

Mr. Sebastian Nutini, Supervisor
Trail School District

Mr. Frank Perehudoff, Teacher
Castlegar School District

Mrs. Jean Ryley, Primary Co-Ordinator
Cranbrook School District

Mr. Dan Shimizu, Teacher
Trail School District

Mr. Mac Sinclair, Selkirk
Community College, Castlegar

Mr. Satoshi Uchida, Teacher
Castlegar School District

Mrs. Adele Yule, Homemaker
Castlegar

RICHMOND REVIEW PANEL

Mr. Dominic Alvaro, Teacher
North Vancouver School District

Mr. Peter Beugger, Elementary
Consultant, North Vancouver School
District

Mr. Robert Campbell, Teacher
Richmond School District

Ms. Evelyn Grimston, Teacher
Burnaby School District

Mr. Don Heise, Teacher
Burnaby School District

Mr. Henry Janzen, Teacher
Delta School District

Mr. Ted Kagetsu, Teacher
Richmond School District

Mrs. Madeline Noble, School Board
Member, Richmond School District

Ms. Linda O'Reilly, Teacher
Vancouver School District

Mr. Garry Phillips, Teacher
New Westminster School District

Mr. Bernie Pregler, Continuing Education
Administrator, Coquitlam School District

Mr. Dave Rivers, Education Services
Officer, British Columbia School
Trustees Association, Vancouver

Ms. Pat Takasaki, Teacher
Richmond School District

Mr. Alan Taylor, Teacher
Coquitlam School District

Mr. R. Bruce Wood, Teacher
Vancouver School District

HANEY REVIEW PANEL

Mr. Ken Abramson, Teacher
Chilliwack School District

Mrs. Mary Ammerlaan, School Aide
Maple Ridge

Mr. J. Allistair Brown, Chartered
Accountant, Maple Ridge

Mrs. Helen Casher, School Board
Member, Maple Ridge School District

Mr. Mike Cianci, Teacher
Kamloops School District

Mr. Richard Collins, Teacher
Coquitlam School District

Mr. James Connor, Supervisor
Maple Ridge School District

Mr. Neville Cox, School Board
Member, Mission School District

Mr. Alan Davies, Teacher
Coquitlam School District

Mrs. Grace Dilley, Curriculum
Advisor, Surrey School District

Mr. George Eldridge, Teacher
Kamloops School District

Mr. Len Fowles, Principal
Kamloops School District

Mr. Roger Freschi, Teacher
Coquitlam School District

Mr. Ralph Gardner, Supervisor
Coquitlam School District

Mr. Kiyo Hamade, Teacher
Langley School District

Mrs. Lynda Haylow, Homemaker
Maple Ridge

Mr. Peter Koropatnick, Teacher
Chilliwack School District

Mr. Roy Kurita, Teacher
Surrey School District

Mrs. Ozan McSweeney, Teacher
Chilliwack School District

Mrs. Marion Mussalem
Homemaker, Maple Ridge

Mrs. Mary Wright, Teacher
Langley School District

VICTORIA REVIEW PANEL

Mr. George Atamanenko, Town
Planner, Victoria

Mrs. Jean Barnes, Teacher
Gulf Islands School District

Dr. William Bloomberg, Forest
Chemist, Victoria

Mr. Geoff Booth, Teacher
Nanaimo School District

Mrs. Kirsten Cox, Teacher
Qualicum School District

Mr. William Dale, Teacher
Qualicum School District

Mr. John Epp, Teacher
Sooke School District

Mr. David Harris, Teacher
Victoria School District

Dr. Harold Knight, School Board
Member, Victoria School District

Mrs. Helga Lenke, School Board
Member, Lake Cowichan School District

Mrs. Rosemarie Lowe, Teacher
Sooke School District

Mr. Daryl McIntyre, Principal
Sooke School District

Mrs. Betty Morphet, Teacher
Lake Cowichan School District

Mrs. Margaret Nelson, Homemaker
Victoria

Mr. Arthur Olson, Principal
Qualicum School District

Ms. Linda O'Reilly, Teacher
Vancouver School District

Mrs. Margaret Strongitharm Teacher
Nanaimo School District

Mr. Brian Tetlow, Teacher
Victoria School District

Dr. James Vance, Faculty of Education
University of Victoria

Appendix C: Mathematics Curriculum Revision Committee

Review Panel with the Mathematics Revision Committee

In October of 1976, the Contract Team met with the following members of the Mathematics Revision Committee to obtain their opinions on the proposed design of the mathematics assessment:

Mr. James Bourdon, Supervisor, North Vancouver School District

Mr. Ronald Edmonds, Teacher, Victoria School District

Mr. Earl Johns, Teacher, Vancouver School District

Mr. Stan Heal, Teacher, Courtenay School District

Dr. Elizabeth Kennedy, Faculty of Arts & Science, University of Victoria

Mr. William Kokoskin, Teacher, North Vancouver School District

Mr. George Nachtigal, Teacher, Abbotsford School District

Mr. Willard Dunlop, Consultant, Curriculum Development Branch, Ministry of Education

Appendix D: Mathematics Assessment Interpretation Panels

INTERPRETATION PANELS

The following three panels contributed to the interpretation of test results by rating the pupil performance on each item.

Grade 4 Test Interpretation Panel

Mr. Jack Allen, Supervisor, Cranbrook School District
Mr. James Bourdon, Supervisor North Vancouver School District
Mrs. Jacquie Boyer, School Board Member, Coquitlam School District
Mrs. Grace Dilley, Curriculum Advisor, Surrey School District
Miss Evelyn Grimston, Teacher, Burnaby School District
Mrs. Jean Hall, Homemaker, Vancouver
Mrs. Helen MacDonald, School Board Member, Mission School District
Miss Pat Montgomery, Teacher, Vancouver School District
Miss Pat Pender, Teacher, Vancouver School District
Mr. Ed Richmond, Faculty of Education, University of Victoria
Mrs. Anne Robarts, Teacher, Vancouver School District
Mrs. Shirley Rudolph, Teacher, Vancouver School District
Ms. Pat Takasaki, Teacher, Richmond School District
Dr. John Trivett, Faculty of Education, Simon Fraser University
Mrs. J. L. Wisenthal, Homemaker, Vancouver

Grade 8 Test Interpretation Panel

Dr. Irving Burbank, Faculty of Education, University of Victoria
Mr. Robert Campbell, Teacher, Richmond School District
Mr. Richard Collins, Teacher, Coquitlam School District
Mrs. Ishbel Elliott, School Board Member, Richmond School District
Mrs. Barbara Girling, School Board Member, Surrey School District
Mr. Don Heise, Teacher, Burnaby School District
Mr. Henry Janzen, Teacher, Delta School District
Mr. William Kokoskin, Teacher, North Vancouver School District
Mrs. M. Mussalem, Homemaker, Maple Ridge
Mr. Tomo Naka, Principal, Nelson School District
Mr. Sebastian Nutini, Supervisor, Trail School District
Dr. Douglas Owens, Faculty of Education, University of British Columbia
Mr. Thomas Poulton, Teacher, Delta School District
Mr. Brian Tetlow, Teacher, Victoria School District

Grade 12 Test Interpretation Panel

Mr. Dominic Alvaro, Teacher, North Vancouver School District
Dr. Thomas Bates, Faculty of Education, University of British Columbia
Mr. Peter Benson, Director of Education, Institute of Chartered Accountants, North Vancouver
Mr. Neville Cox, School Board Member, Mission School District
Mr. Michael Downing, Supervisor, West Vancouver School District
Mr. John Epp, Teacher, Sooke School District
Mr. Ian Hooper, Teacher, Vancouver School District
Dr. Ted Horne, Faculty of Education, University of Victoria
Mrs. Diane McKendrick, School Board Member, Powell River School District
Mr. Frank Perehudoff, Teacher, Castlegar School District
Mr. Bernie Pregler, Continuing Education Administrator, Coquitlam School District
Mr. Mel Richards, Principal, Richmond School District
Mrs. Ona Mae Roy, President, B. C. Home & School Federation, Port Moody
Mr. Alan Taylor, Teacher, Coquitlam School District
Mr. R. Bruce Wood, Teacher, Vancouver School District